TECHNICAL SCHOOL AND COLLEGE BUILDING.

E C Robins, F S A. Architect

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THE GREAT HALL.

MERCHANT VENTURERS' SCHOOL, BRISTOL.

TECHNICAL SCHOOL AND COLLEGE BUILDING

A TREATISE ON THE DESIGN AND CONSTRUCTION OF APPLIED SCIENCE AND ART BUILDINGS, AND THEIR SUITABLE FITTINGS AND SANITATION, WITH A CHAPTER ON TECHNICAL EDUCATION

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PREFACE.

In presenting this volume to the profession and to the public, I am deeply sensible of its shortcomings, yet I have been emboldened to undertake the labour involved in its preparation, in response to the numerous applications made to me by both British and Foreign correspondents engaged in the construction or promotion of Technical School Buildings; and in the hope that, by so doing, I might further the cause of Technical Education generally.

The generous appreciation which men of science have accorded to my privately circulated papers on the subject, has encouraged me to put the information I have gathered, and brought down to the present period, into the form of a convenient book of reference.

I embrace this opportunity to thank the numerous architects, professors and gentlemen who have so kindly assisted me in the collection of the facts recorded, and the examples illustrated.

E. C. R.

June, 1887.

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INTRODUCTION.

The studies recorded in this volume have resulted from the conviction of the Author that the more general spread of Technical Education is of the greatest importance to this country, as a means of maintaining the superiority we have hitherto enjoyed as skilful designers, manufacturers, inventors, and handicraftsmen.

By the original research of men of science, we are daily being brought face to face with Nature's laws as well as Nature's loveliness, and experimental knowledge is coming to be preferred to empirical teaching without the experimental test, because it is found that only in this way can theory and practice harmoniously coalesce and form new combinations culminating in fresh invention. In fact, intelligent doing, the result of artistic practice and scientific understanding generally, is rapidly superseding abstract thinking in dead languages and unapplied mathematical formulæ in this busy world of ours.

"It is through its practical value," say Professors Ayrton and Perry, "that a knowledge of mathematics must come; and any teacher who refuses to consider the instinctive preference of his pupils to reason about *things* rather than about *ideas*, is a man who persistently refuses the powerful aid of Nature."

"The danger in all these technical schools," said Professor Huxley in a letter to the Author, "is this, that the scientific teacher generally begins his work on the high and dry method, and fills the mind of the student with mere verbal formulæ before there is any practical experience by which these ghosts can be embodied."

But while we may safely leave the educational *modus operandi* in the hands of our leading professors, it is manifest that so great a revolution in the systematic education of the period points to a corresponding change in the design of the buildings required for its development.

The object to be attained has been most happily paraphrased by Lord Shand in the third proposition of his opening address, delivered before the Watt Institution and School of Arts, Edinburgh, viz., "*Without* attempting the establishment of trade schools it is proposed to *add* to the teaching of pure science, instruction in the practical application of

scientific principles to the operations of the trade (or profession) in which the student is engaged, by *laboratory practice,* as distinguished from mere lectures on scientific subjects.

"In this way the student, having first acquired a certain amount of general scientific knowledge, as the basis for advanced education, is thereafter taught the application of science by actual laboratory experiments and practice of a kind bearing on the trade (or profession) he is to follow; lectures by the teacher are by no means dispensed with, but are made subordinate to the actual work in the laboratory, for which they are intended to be a guide and an assistance."

My own interpretation of what should be comprised in the term "Technical Education" is very comprehensive, viz., that it is the complement and crown of all utilitarian education as contrasted with literary culture only—it is pure science carried to its legitimate issue: that is to say, its varied applications to human requirements; it is the practical application of scientific principles to special objects and purposes, and it is as necessary to professional men as it is acknowledged to be to manufacturers and artisans.

Technical education has at last obtained a firm hold of the public imagination, and the Government of the day long since deemed the times ripe for the establishment of a Royal Commission to inquire into the provisions made for its spread both here and abroad, and to report the result of their investigations with such recommendations as their experiences might authorize them to make. This has resulted in the publication of important papers full of facts and figures invaluable for reference.

The general question from an educational point of view has been dealt with in the *first chapter*, for the most part written shortly after the Author's return from Germany, in 1882.

In a paper read at the Educational Conference of the Health Exhibition, Dr. Armstrong indicated the lines upon which he believes scientific teaching should proceed in this country; and his able address to the Chemical Section of the British Association, at its Aberdeen meeting, is worthy of careful perusal; so also is the important inaugural address of the President, Sir Lyon Playfair. "My argument is," says he, "that no amount of learning *without science* suffices, in the present state of the world, to put us in a position which will enable England to keep ahead, or even on a level with foreign nations, as regards knowledge and its applications to the utilities of life." Others have followed Sir Lyon's lead, and enforced the necessity for a more general and systematic teaching of applied science in buildings erected for the purpose and suitably fitted up.

Sir Philip Magnus has well defined the scope and order of procedure adopted by the City and Guilds of London Institute for the Advancement of Technical Education. Commencing with selected scholars from elementary schools and embracing every subsequent grade, he points out the provision which has been made for all classes of the people—by Technological Examinations, by courses at the Kensington Art Schools, and at the Finsbury Technical College of Science and Art for Apprentices and Workmen—culminating in the higher scientific culture carried on at the Central Institution in Exhibition Road, which it is expected will ultimately bear comparison with any foreign school, and supersede the supposed necessity for English students going to Germany to complete their scientific education.

There are those who would narrow the operations of the City and Guilds of London Institute to a special class of students, but it has wisely considered that efficient elementary scientific teaching is best attained when it is associated with the more advanced curriculum of high-class qualifications, and that to control the Technical Education of the counties, the Metropolis must be provided with the best model institutions of every grade from the lowest to the highest. This is to give a national character to its work, and to awaken in the minds of our fellow-countrymen an appreciation and respect akin to that which the Guilds enjoyed prior to the Reformation.

It was a wise thing of the Government of the day to appoint the Organizing Director and Secretary of the Guilds Institute, one of the members of the Royal Commission on Technical Education, thus giving to him the exceptional experience, which in no other way could have been so well translated into action, as by introducing the knowledge acquired to the chief officer of the City and Guilds of London Institute. With the view of inducing others to study the remarkably complete report which the Commissioners have produced, the Author has given an analysis of the Second Report of the Royal Commissioners, which forms the subject of the *second chapter.*

The example of foreign nations has shown that the promotion of Technical Education will be greatly advanced by the provision of suitable buildings, suitably fitted for their purpose, and therefore it is that the Author has collected and compared some of the most notable and interesting of *Foreign* laboratories. In the *third chapter*, a general description of these is given, illustrated by plans of the principal floors. In this way the Author has striven to present to the scientific world, and promoters of similar institutions, the result of much study and travel, which he trusts may issue in the saving of much time and labour, and wasted energy, resulting from repeatedly going over the same ground; and also by his Comparative Analysis of the best examples, aid in the development of that discriminating power, without which the weaknesses of a design are as likely to be imitated as its strong points.

In the *fourth chapter* a series of *English* examples is given, nearly all of which have been completed and opened since the first chapter was written. It will be observed that our native independence of character asserts itself in a marked manner, and considerable originality is displayed; the objects sought to be accomplished have generally been attained, at all events wherever the professors and the architect have had the opportunity of consulting before the preparation of the plans.

The *fifth and six chapters* are devoted to the description, analysis, and illustration of the various fittings required to render technical buildings suitable for their educational purposes. The importance of this branch of the subject cannot be too strongly insisted on, because these fittings are not independent of the structure in science laboratories, but in most cases are an integral part of it. The heating and ventilation alone necessitate the preconception of what provision is to be made in the solid walls or floors for the admission or extraction of fresh and fouled atmosphere, which provision must be in the neighbourhood of the fittings wherein the noxious fumes are generated; and the system of withdrawal from these must be in the same direction as that of the general room ventilation, which is of course simultaneously going on.

No room or combination of rooms can be said to be properly designed, upon the plans of which the whole of the intended fittings have not been arranged before their erection; and if promoters of such projected buildings were to insist upon the association of the architect with the several professors by whom they are to be used, they would save much costly subsequent variation in the plans, which after all can never be so perfect as they might have been had previous consultation been enjoined.

The *seventh and eight chapters* not only describe the different systems of heating and ventilation, instancing various examples more or less desirable, but the Belgian mode of calculating the contemplated results beforehand is also given for what it is worth, and that is a great deal, if only the mechanical difficulties were better understood and provided for in execution.

In the *ninth chapter* middle-class school buildings generally are reviewed, which are rapidly becoming fitted with science laboratories. Since the delivery of the Author's lecture on Buildings for Secondary Education, at the Society of Arts in 1880, he has himself been required to add chemical laboratories to several of the buildings mentioned therein; and in the sixth chapter he has given an illustration of the new laboratory recently erected for the North London Collegiate School for Girls. Laboratories have also been added by him to Milton Mount College, Gravesend, and the Congregational School at Caterham. Nothing is more illustrative of the growth of the desire for technical instruction than the necessity which has arisen for science laboratories in secondary schools, except perhaps their provision for the great Universities of Oxford and Cambridge.

The *tenth chapter*, on the Relation of Sanitary Science to Civil Architecture, is an essay originally written by request and delivered before the Royal Institute of British Architects in 1880; it is in its right place at the close of a book on Technical School Building, for no other structures are more dependent for their success on good sanitary conditions.

In conclusion I may remark that a full description of the Merchant Venturers' School at Bristol is given in the fourth chapter. The building having been erected from the designs and under the superintendence of the Author, a view of the exterior and interior forms the frontispiece of this volume. The plans of each floor appear in their proper place in the body of the book, and are presented as a type of the kind of secondary technical school-buildings now required in all our provincial towns.

The completion of this enterprise of the Merchant Venturers, and the formal opening of the building by Sir Frederick J. Bramwell, F.R.S., took place on the 25th July, 1885, in presence of the Mayor of Bristol, the Master and Wardens of the Society of Merchant Venturers, the local magnates, and an influential circle of the representatives of science, art, and education. The following is a portion of Sir Frederick's address delivered on the occasion, extracted from the *Times* newspaper, which forms a fitting climax to this introductory chapter:—

" That meeting," said Sir Frederick, " was not to initiate something new, for, as had been said, the work had gone on for thirty years; it was not to mark a birth, but to mark a progress, not the full development, or anything like it, but a stage, for they would hope that not many years would elapse before an audience as numerous and as earnest as that

he saw before him would meet in Bristol to celebrate some further marked step in the development of Technical Education in this city.

"What was the object in giving this Technical Education? The primary object was to enable men and women to earn their living better than they could otherwise do. It might be said that that was a very low motive, but was it a sordid motive when a man said in starting life, 'How am I to earn my living by my own exertions, maintain my family, and be contented and happy?' A man who set that task before him had not a low motive, but one which if steadily pursued would make him a worthy citizen; and the nation made up of units of that character became great and prosperous. Therefore the primary object of such education was to teach men engaged in industrial pursuits to conduct them in a manner which would redound to their happiness and material prosperity, and this would redound to the prosperity and welfare of the whole nation. When a man had the advantage of Technical Education he was enabled to look at the experience of the past in a totally different manner from the man who had not that advantage, because he knew the principles upon which that experience was based, and knew when it was applicable or inapplicable." Having illustrated this by reference to iron-making and dyer's work, he said: "The man best fitted to combat all these difficulties and become an active and successful pioneer was one who combined scientific teaching with practical knowledge.

"It was unlikely that they had any one present who doubted whether there was any necessity for this new teaching, or whether the old-fashioned rule of thumb was the best. The markets of this country were open to the whole world, and our colonies were indifferent whether produce came from the mother country or foreign countries; so the English manufacturers and traders had to meet at home and in the colonies, the manufacturers and traders of the whole world unaided by any protection. Whatever his determination, the Englishman was badly weighted in his struggle with his foreign competitor if the latter had the means of applying science to his industry when the former had not.

"In London they were doing good work of this sort, one of the branches being technological examination; during the past three years the number of those who had come up had more than doubled—from 1900 to 3900. That increase did not arise from the governing body relaxing the examination; on the contrary, they thought it right to add to the stringency of the examination; so that the best judges of all, the very men whom they wished to instruct, themselves proved that they valued this instruction. It could not now be said that they were endeavouring to force on an unwilling people the advantages of an education the value of which they did not recognize; the contrary was the fact, and thus they had the encouragement arising from appreciation of their efforts.

"Their architect, Mr. E. C. Robins, was a Past Prime Warden of the Dyers' Company, one of the most active members of the Executive of the City Guilds, and the interest which Mr. Robins took in that work led him to apply his great talents and architectural experience to this particular kind of structure, in this instance with benefit to the City of Bristol. The building must commend itself to them both externally and internally as an example of good English domestic architecture. All who had gone over it must feel that in the more important matter, the fitness of the building to the end, they had ample proof that

Mr. Robins was a most competent architect for the purpose, and had brought to the work an amount of thought, labour, and care, which would benefit the citizens for years to come."

He concluded by expressing his sincere belief and earnest hope that there would flow from this school all those benefits which the Guild desired and expected, and asked the meeting to join with him in expressing hearty approval and thanks to the Society for furnishing Bristol with that magnificent school, which he then formally declared open.

Since the opening of the above building the Author has visited many science schools recently erected in the North of England and elsewhere, accounts and illustrations of some of which are included in this volume; and the interest is a growing one, while the recent discussion in the public journals on the importance of establishing schools of Forestry and Agriculture is a healthy sign of the times.

The year of the Queen's Jubilee is likely to be best remembered as the year which gave birth, not only to the National and Colonial Institute, but to numerous equally useful, if less ambitious, projects, all tending to the increase of commercial prosperity, the multiplication of handicraft industries, the extension of science and art applications, and the development of Higher Technical Education.

CHAPTER I.

ENGLISH AND FOREIGN TECHNICAL EDUCATION.

A BOOK on technical school and college building presupposes some acquaintance with Technical Education itself, at all events so far as the methods employed affect the construction of the buildings in which technical education is to be given. I shall therefore devote this opening chapter to a consideration and contrast of English and foreign methods, taking as the basis of my remarks, the paper read by me at the Society of Arts, in May, 1882. In the five years which have since elapsed, there will be found in this book instances of remarkable progress, not only in the number of buildings devoted to the work, but in the better understanding of the objects in view and of the means of attaining them. At that time it was impossible to listen to the various opinions from time to time expressed, without being struck with the confusion of ideas prevailing, resulting from indefinite generalizations made from a variety of standpoints, and usually empirically enforced as the only panacea for all the evils, real and fancied, which afflict the body politic of our industrial communities.

One enthusiast connects technical education with the development of manual dexterity, another with mental activity and scientific training, a third with a combination of both in one and the same person. One thinks the study of the application of scientific principles to industrial pursuits should precede apprenticeship, another that it should follow it, and a third that it should go on concurrently with it. One thinks our apprenticeship system the best, another the worst, and a third denies its present existence and sighs for its resuscitation, or the substitution of something else in its place, neither English nor foreign, but emphatically suited to the needs of the age we live in, and the social peculiarities we represent. One thinks technical education should commence in our primary schools, another in our secondary schools, and a third that every school should have its technical side as sharply developed as its classical proclivities were, are now, and ever shall be. One thinks it is our artisans who are at fault, another their masters, and a third the altered conditions of both; but all are agreed that the maintenance of our acknowledged superiority in technical matters cannot long be continued while we ignore the deficiencies which may exist in our present practice, and complacently shut our eyes to the advantages which other nations are affording to their populations. The energetic, independent, self-helpful qualities of the national character remain, its individuality is as strongly marked as its insular position and prejudices; but as time rolls on, the conditions of life and labour are changed, and it follows that the ancient educational customs of the people, the old world order of things, must needs change too, to meet the pressing

wants of a superabundant population, and a revolution of thought and feeling, place and circumstance, the result of fifty years of scientific development and commercial prosperity.

In this brief period of time, gas has superseded oil lamps, and the electric light is extinguishing gas, as the sun eclipses all lesser luminaries. We see, we read, we write, we speak, we fetch and carry by electricity and with the speed of lightning. Railroads have supplanted stage-coaches and inland canal navigation, steam-vessels have well-nigh superseded sailing craft, as iron has wood, and steel has iron in their construction, and armour plating replaced the "wooden walls of Old England." Even the steady triumph of steam-power is menaced by the conservation of electrical energy and its ready adaptability to almost every requirement of man. Chemistry, physics, mechanics, biology, geology, mineralogy, crystallography, metallurgy, telegraphy, &c., are, comparatively speaking, new sciences, the growth and applications of which have originated new centres of labour and thought, and constructed a new people out of an old stock, with new surroundings, new tastes, new wants, new purposes, hopes, and aspirations.

The intellectual and social condition of the industrial population and the character of the education it should receive to fit the national mind to cope with the national progress, cannot be met by an extension of scholastic institutions based on the requirements of the middle ages. Yet this is the spirit which has dominated our Universities, and until very lately, no concessions have been made to the reasonable demands of progressive civilization. Secondary education has followed suit, and the study of the intricacies of dead languages has been thought more profitable than the study of God's laws hidden away in the universe and revealed only in answer to scientific research. Primary education was left to the various religious denominations to wrangle over, until the tardy establishment of the School Boards; but now the hopes of all men, untrammelled by vested interests or party feeling, have come to centre round the roots of the national educational tree, and not with its decaying branches, to believe in the truth of *things*, as well as the form of sound *words*.

Every day the public learns the better to appreciate the effort made in the right direction, and in many ways we have no cause to fear competition. The world-wide introduction of machinery has minimized handicrafts and magnified mechanical production, with the unexpected but consequent result of raising the value of purely artistic developments everywhere, and this country is not behind others in meeting the demand.

The influence of South Kensington upon the artistic productions of the country has been greatly beneficial, and the turn that fashion has taken in architecture has favoured the process; for whereas heretofore the external embellishment of a building was the chief aim of the designer, now the attainment of interior comfort, beauty of detail, and harmony of colour is the leading idea. Fecundity of artistic power in design is genius rather than talent, an instinct rather than an acquirement, except so far as its means of expression are concerned, and thus it is that the individuality of the English artist is beginning to tell abroad, and the originality of English taste in architectural and ornamental design is rapidly supplanting continental conventionalism. It is to England the Germans come for Christmas cards, original ornamental pottery, patterns for embroidery, &c., &c. And in Vienna,

lately, I could scarcely buy a ***souvenir*** that was not adorned with cuttings from Kate Greenaway's charming crudities. The new Industrial Art School and Museum at Vienna is professedly based on the example of South Kensington.

The fact appears to be that academic acquirements are necessarily rather imitative than creative. The assimilation of the thought and fancy of other minds may cultivate our own, but does not ensure us independent powers of thought and action.

It is obvious, therefore, that something is wanted between the two extremes of academic precision and individual licence. If French and German powers and opportunities of acquisition could be engrafted on English intuition, the fruit borne would be a more perfect representation of art than either has as yet separately achieved. The importance, therefore, of securing for Great Britain and Ireland some of the educational advantages enjoyed by our continental neighbours is every day becoming more obvious and better understood, and it has already given occasion for the appointment of the Royal Commission on Technical Education, the preamble of whose instructions commences thus :—

"We have deemed it expedient that a Commission should forthwith issue to inquire into the instruction of the industrial classes of foreign countries in technical and other subjects, for the purpose of comparison with that of the corresponding classes in this country; and into the influence of such instruction on manufacturing and other industries at home and abroad."

The Royal Commissioners have done wisely, as I think, in publishing their report in sections, and clearly defining the classes with whom they are about to deal.

1st. The instruction of the proprietors and superior managers engaged in industrial pursuits.

2nd. That of the foremen engaged therein.

3rd. That of the workmen.

Their first report dealt with primary education only, and almost exclusively the elementary education of France, and the extent to which technical education is comprised therein. The second report is reviewed in the next chapter.

In the meantime let us consider—

1st. The technical education of the working classes.

2nd. That of their superiors and overlookers.

It is extremely gratifying to find that the conclusion to which the Royal Commissioners have come, with respect to the relative value of the technical teaching given in France and England, is so favourable to us. They state that—

"It will be manifest from the description we have given of the ordinary elementary and apprenticeship schools in France, that, with the exception of the very recent introduction of manual work into the schools of Paris, and of the instruction in trades, provided in a few cases, for a small number out of hundreds of thousands of apprentices, French workmen generally, as distinguished from those employed as foremen, or aspiring to that position, have not till now, except as to systematic teaching in drawing, possessed during the school age better instructions than persons in a similar condition in this country."

From this it would appear that, in their judgment, it is not in the technical education of the ordinary working classes that we shall find the differences we are seeking to discover

which is the conclusion arrived at by the Conference of the Society of Arts in 1868 (hereafter given in detail).

On referring to the reports from her Majesty's diplomatic and consular agents abroad respecting the condition of the industrial classes in foreign countries, dated 1870, and made in answer to the circular of the late Lord Clarendon, primary education (which is gratuitously given in Paris, and in the provinces too, if the parents are poor) is said to comprise (in addition to the three "R's") the physical sciences, history, geography, mathematics and surveying, and even drawing, foreign languages, book-keeping, and geometry, by the laws of 1850, which also provided for the establishment of evening schools for adults over eighteen years of age, and apprentices over twelve. From this it would appear that the elementary technical education of the masses in France had, at all events, a good start of us.

But the report of the French Commissioners on Technical Education in 1865 reveals a state of things much akin to our own, so far as these ordinary workmen are concerned; and in the great industrial centres, and especially in Paris, there was remarked by them "a growing tendency towards abandoning the system of apprenticeship, substituting the employment of lads as drudges, and as they began to learn by force of example the masters raised their wages, which was their only encouragement to improve themselves."

Nevertheless, the Schools of Arts and Trades existed at Chalons, Angers, and Aix, and the *Conservatoire des Arts et Métiers* in Paris, where workmen so fortunate as to be admitted might raise themselves to the position of skilled artisans and foremen in factories and workshops without expense, if they had sufficient energy to do so; no such corresponding advantage existing in this country. In the *Conservatoire* in Paris the courses were confined to lectures on science applied to industry, expressed in terms easily understood by the less instructed, but the pupils had access to a magnificent library and museum of models and machinery of art-workmanship. In the Schools of Arts and Trades the lads worked out the usual period of apprenticeship in special factories, in which a few hours of the day were devoted to the completion of their primary education. Of the twelve hours of instruction, five were devoted to theoretical instruction, such as geometry and mathematics, and seven hours to practical work in the workshop, where smiths, founders, turners and wheelwrights, &c., were taught their trades, great attention being paid to instruction in drawing, as the art by which so many questions of mechanical science are solved.

The result of this system was not altogether satisfactory, however. The students expected to be foremen, not workmen, and were disappointed at finding that their fellow-workmen, without theoretical education, over whom they expected to rule, earned higher wages on account of their superior skill in manual labour.

In Switzerland, where education is more general, such expectations would not arise. Exceptional privileges are the proper complement of exceptional training. Since 1870 manual work has been largely introduced into the primary schools of Paris, showing that, on the whole, they find the advantages greater than the disadvantages. And in the school of the Rue Tournefort rudimentary trade teaching is combined with ordinary elementary instruction, and workshops are being attached to some forty or fifty of the primary schools.

French apprenticeship schools for workmen have also been established, both as boarding and day schools. The municipal apprenticeship school of the Boulevard de la Villette in Paris is a day school for workers in wood and iron, and was established some twelve or fourteen years ago. Similar institutions exist in the provinces, notably at Havre. The Royal Commissioners report that—

"The authorities of the city of Paris deemed the experiment of the apprenticeship teaching in the school of La Villette sufficiently successful to induce them to erect a number of similar schools in other parts of the city;"

And a sum of 80,000*l.* was voted for the purpose; the Prefect of the Seine reporting—

"That in consequence of the virtual abolition of apprenticeship in most trades, and owing to the specialization and subdivision of manufactures resulting from the introduction of machinery, the number of skilful and intelligent workmen in all branches of industry and art manufacture has decreased, and that the standard of technical knowledge has been lowered."

That this is precisely the case in England cannot be universally admitted. We have improved, and are improving, though not nearly so fast as we ought; and although the Royal Commissioners do not recommend the costly experiment of building similar schools in England, they still feel that, to give value to the manual dexterity which is best acquired in the ordinary workshop, instruction in the use of tools during the elementary school age would greatly facilitate the learning of a trade, and shorten the time of probation, and they would be glad to see this kind of manual instruction introduced into some of our elementary schools. From my professional point of view, the provision of good common workmen in all the trades connected with building is a matter of vital importance. The worry of our lives as architects, and the shortening of them too, is the anxiety attendant on the difficulty of getting reasonably good work done, except by picked men at high wages attached to the leading firms.

Now let us look at Germany: what is she doing for the working classes? Very much the same as Switzerland, who preceded her and Austria in experimental technical education, but who is surpassing all the world in the provision made for higher technical education. I say, what is Germany doing for the masses of its working men?

Professor Weinhold, of Chemnitz, writes to me, in answer to this question, as follows:—

"Generally the working clases get no technical education beyond what they learn in the workshops during their apprenticeship days. A few of them visit a foreman's school or any of the *Fachschulen* which exist for the different branches of industry, and some, after having gained enough money by their handicraft to live, devote one or two years to the school."

Professor Lunge, of Zurich, writes me:—

"There are schools, both in Germany and Switzerland, intended for giving a proper technical and half-scientific, but always practical education to workmen, so as to fit them for foremen's places. These schools have proved very successful indeed, quite as much as the Polytechnic schools in their higher aims, which latter do not touch the working classes in the ordinary sense."

Dr. Witt, of Mulhouse, writes me thus:—

"Primary schools in Germany take pupils from their sixth to fourteenth year. The education is compulsory. There are three classes, one of which every child must attend.

"(a) *Volksschule* (the Elementary or Board School).—Here the children learn in addition to the three R's, history, geography, natural history, and singing.

"Children who attend this school generally finish their education with it. They then become factory boys or farm boys or apprentices to artisans, until their twentieth or twenty-first year, when they have to become soldiers for three years. If after the service they are still good for something, they return to their previous occupation, viz. they become workmen, labourers, or artisans' assistants, until they get a chance to become artisans themselves.

"(b) *Höhere Bürgerschule* (the Lower Middle-class School).—The same subjects are here taught, but more carefully. This is the school selected by the parents of children who are intended to have some more training, but no university education.

"(c) *Vorschulen des Gymnasiums.*—Secondary schools preparatory for college education, and attached to colleges; same subjects taught, together with some Latin. These are for boys who are intended to go to the Gymnasium or College."

The above are the primary schools, besides which there are other voluntary schools with a marked object, as the *Fortbildungs-Schulen*, intended to instruct boys leaving the primary school (*Volksschule*) at the age of fourteen, and to train them for becoming artisans; and the *Technikums*, which are schools entirely independent of all others, and generally supported by private means, or self-supporting. Their chief object is to educate practical engineers, foremen for workshops, dye-houses, &c. It is obvious that the scientific side of the compulsory primary education on the Continent is but little or no more advanced than our own, and the great majority of working men go straight to the workshop therefrom, while a few take advantage of *Technikums* or *Fortbildungs-Schulen* preparatory thereto. But all suffer from the disadvantage of passing the desultory life of a soldier for three years, before they can earnestly set about their business.

Professor Perry thinks that the teaching formulated by the Irish Commissioners for Model Schools in Ireland is probably better than any other scheme of primary instruction.

The preparation necessary for passing the examinations of the Science and Art Department, or of the Technological Examinations of the Society of Arts, now taken over and so remarkably extended by the City Guilds, would alone seem to counterbalance the so-called advantages of foreign systems of technical education for the working classes, to say nothing of the broken continuity of education, and prejudicial effect of three years' soldiering.

Professor Sylvanus P. Thompson, of Bristol (now the Principal of Finsbury Technical College, London), is, nevertheless, an admirer of the foreign system; and Mr. H. Solly has also written a pamphlet on the same side, and many others are strong advocates of it.

It was, therefore, a wise step on the part of the City and Guilds of London Institute for the Advancement of Technical Education—the chairman of whose executive is no less a person than Sir Frederick Bramwell, F.R.S., and whose members are picked men from the contributing companies they represent—to call in the aid of such men as Sir William Armstrong, Mr. Bartley, Colonel Donnelly, Captain Galton, Professor Huxley, and Mr.

Trueman Wood, to advise with them at the starting of their great undertaking—whose essays are bound up with the first report of the Executive Committee to the General Committee of certain of the Livery Companies of London. All these gentlemen were unanimously of opinion,—

1. That the teaching of the practical part of the particular trade or manufacture should not be carried out in certain establishments auxiliary to those devoted to theoretical instruction, and concurrently given in connection therewith.

2. That the practical part should be left to be acquired in workshops and manufactories, by means of apprenticeship or otherwise, supplemented only elsewhere.

3. That the function of the teacher should be confined to instruction in the various arts and sciences connected with industrial undertakings, and especially in their practical application.

It would seem that these views have been concurred in by the Presidents of the Royal Society, the Chemical Society, the Institution of Civil Engineers, as well as by the Chairman of the Society of Arts, since associated with the City and Guilds Institute, and acting as members of their Executive Committee. At all events, the result has been that they (the Guilds) resolved,—

1. To establish at South Kensington, at a cost of 100,000*l.*, a central institution, or High School of Applied Science and Art for advanced students and teachers, to include courses of free popular lectures, as at the *Conservatoire des Arts et Métiers*, Paris.

2. To establish Science and Art Trade Schools in the north and south of London, at a cost of 30,000*l.* and upwards; morning and evening classes and lectures, and laboratory work for boys, apprentices, and workmen generally, and of all ages.

3. Grants in aid of local schools and classes suited to the industries of each locality.

4. Exhibitions in elementary schools to be held in trade schools.

5. Exhibitions in trade schools to be held at the central college.

6. Extended systems of examinations in technology, based on that of the Society of Arts.

7. The affiliation or absorption of kindred societies, as the Art Carving School, the Horological, the Artisans' Institute, the City Art Schools, and others.

But we have yet to decide between the many opinions respecting primary technical teaching. Professor Huxley says,—

"I do not think that much good is to be done by attempting to deal with the trades directly in the scientific education of the masses of the people. The great object appears to me to be, to construct such a scheme as should enable you to sift out and get hold of the men who have really scientific ability, give them a fair scientific training, and you may trust to the arts getting all they want out of them."

Professor Fleeming Jenkin says, "If you mean by technical education, attempting to teach a man his business by a college course, I think it a very mischievous delusion indeed; but if you mean that in addition to his practical training, you would give him some theoretical training, some technical courses, I think that would be very useful indeed."

Professor Ayrton says,—

"By a 'technical school,' I understand not one in which the manipulation or routine

of a trade is taught, but a school where a lad receives general instruction in the principles of applied science, and special instruction in the application of these principles to the particular trade he is following, or which he is about to follow."

Professor Ayrton has created for the City Guilds a system of technical education in physics suited to the masses, who have flocked to Finsbury in greater numbers to be taught than was at any time foreseen (between 500 and 600 students being enrolled during the first year), and this in spite of the temporary character of the accommodation then available while the new Technical College was being erected for the accommodation of the professors of physics, chemistry, and mechanics. Professor Armstrong had his own methods of teaching technical chemistry; and the appointment of Professor Perry to the chair of Mechanics ensured an original treatment of that subject, a foretaste of which he had given in his Cantor lectures at the Society of Arts.

At the same time, under the careful direction of Mr. Magnus, the technological examinations which were taken over from the Society of Arts became so popular that, in spite of the standard of efficiency being raised, thousands of students soon presented themselves for examination from all parts of the country in every industry, and thus a sound and sensible system of technical education was inaugurated by the City Guilds, the value of which cannot be overrated. It only requires an extension of the provincial trade schools, and that the School Boards throughout the country should give greater development to Froebel's system of object lessons, and follow it up with elementary classes on mechanical and natural science, taught by the analytical methods employed by Professor Ayrton, to give us a system of natural education for the masses equal, if not superior, to that which has been initiated abroad.

Of these three professors, Mr. Perry alone remains at Finsbury College, Professors Armstrong and Ayrton having been translated to the Central Institution of the City and Guilds of London Institute at South Kensington; and these, in conjunction with Professors Unwin and Henrici, form the chiefs of the educational staff, Professor Unwin holding the office of Dean of Studies.

Professors Thompson, Meldola, and Brophy are the present associates of Professor Perry at Finsbury College, Professor Sylvanus P. Thompson being the Principal.

The success which continues to follow the work at Finsbury College is so great, that it is in contemplation to double the accommodation. This college is chiefly intended for young students, apprentices, and artisans of all ages; and though not exclusively so, may be termed a lower middle-class college.

2nd. I have now arrived at the second general division of my subject, viz. *the technical education of the upper middle classes.* If we have found nothing to alarm us in the contrast between the primary technical education of English and foreign nations, owing to its very recent and spasmodic application, and the limited area of its effective usefulness anywhere, the case is entirely altered when we come to deal with the secondary or higher class teaching.

It is here, if anywhere, that we have met our match abroad. It is here, and nowhere else, that we must look for the resurrection of our old precedence. But Englishmen do not mind being told of their shortcomings; they rather like it than not; it rouses the lion, and makes him rampant; it excites their competitive spirit and pugnacious instincts; it

sets their brains on fire, a fire which, when thoroughly kindled, never goes out till success is again achieved. The persistency of the national character is its salvation—given a leader in whom its faith can be rested, and it is irresistible.

It is not now needful to review the secondary educational provisions made in all foreign countries. They have culminated in the system adopted in Germany and the nations bordering upon it, which has been followed in Sweden and Russia and elsewhere. A paper was read before the Foreign and Colonial Section of the Society of Arts, in February, 1882, on Scientific and Technical Education in Russia, by Professor J. J. Hodgetts, of the Imperial College of Practical Science, Moscow, in which he said,—

"In 1851, we, in England, were ahead of all civilized Europe—why are we so lamentably behind now? From my own experience abroad, the reply would seem to be, that other nations have had a scientific education, while we have had none. Other nations have effected a certain amount of organization, while we seem to stand historically pledged to avoid all systems, and to dread the very idea of organization."

This is one of the first impressions made on an Englishman abroad. The absence of paternal government at home, and the freedom from governmental restriction of any sort in his insular home, so long as he pays his taxes, unfits him to submit to the regulations which are maintained everywhere abroad, and I, for one, do not desire to import them. Our individuality would be gone, our personal energy sapped. No! let us have unity of purpose, instead of uniformity of action. Let us agree that we are lacking in something, and let us all determine to overcome the deficiency, and it will be done—done by ourselves—each in his own sphere and particular domain of industrial work. The scheme should be suited to local requirements, and supported by the commercial magnates of each centre of special industry, our teachers being made independent of results, but allowed to reap the benefit of them. Government payment in the shape of grants in aid should be given in no niggardly spirit, but be in due proportion to the local interest manifested. It should depend not only on the sums voted by personal munificence or municipal local authorities, but on the response made to it in the shape of primary and secondary students flocking to the schools.

Secondary education in Germany (which is not compulsory) is for pupils from their tenth to their seventeenth or nineteenth year. Dr. Witt thus summarizes it:—

"(*a*) The *Gymnasium*, or college, in which is taught plenty of Latin, and a good deal of Greek, German, and a little French; English and Hebrew taught to those who wish to learn, which most do not; a moderate knowledge of mathematics, and a little natural history, geography, singing, gymnastics, drawing, plenty of religion."

Pupils leaving any of the three highest classes (that is, from the seventeenth year) are entitled, as a matter of course, to the one year's instead of three years' voluntary service. For this service they may choose their own time as well as place to join the army. From the gymnasium pupils pass on to the universities.

"(*b*) *Realschule* of the first grade, from tenth to nineteenth year. Here, German, French, and English are taught; a little Latin, and plenty of mathematics; a fair knowledge of natural history, chemistry, physics, &c.; history, geography, singing, gymnastics, drawing, machine-drawing, religion." In short, a manly, self-developing curriculum.

These schools differ very much; thus, in some of them they have no Latin, but practical carpentry and engineering instead. In some they have a fair training in practical chemistry and laboratory work, in others not.

These are the schools from which the *Polytechnikums* and similar institutions draw their supply of students. The Mulhouse Chemical Institute students generally come from them. Numbers of students only go as far as the seventeenth year, and then enter merchants' offices as clerks; others leave still earlier, and become articled pupils, for a term of two or three years, in factories or engineers' workshops.

Like the gymnasium, this school gives to the successful pupils on leaving one of the two higher classes (from the seventeenth year) the right to claim the one year's service. Young men who have not obtained that right by passing through one of these schools, may do so by passing a somewhat difficult examination. No greater incentive to personal educational improvement could be given than the knowledge that two years' military service is avoided by passing such an examination.

"(*c*) *Real-Schule.* Second grade, from tenth to seventeenth year; same curriculum as the first grade, but without the two highest classes. Some of them are entitled to confer upon the pupils leaving the highest class, the right of the one year's service; others do not possess that privilege."

In some mercantile centres, such as Hamburg and Bremen, there exists a rigorous system of training the young merchants, from which nobody is excepted—not even the son of the richest banker; it is this:—The boy must finish at one of the above-named secondary schools. He then becomes for three years an articled pupil in a merchant's office. There he has, during the first year, the duties of an office-boy; during the two following years those of a junior clerk. When the three years are over, he gets a substantial present, according to the zeal he has shown. Now he goes to join the army for one year's service, and when returning he may either enter his father's business, or compete for a clerkship.

Besides the schools above mentioned, there are others with a certain marked object. The *Fortbildungs-Schulen* and the *Technikums* have already been described under the head of primary education, since they are open to students who have had no better preparation for it, and could be entered by any workman who desired to improve his technical knowledge and social position; a valuable provision for the energetic workman, but taken advantage of by much fewer than would be expected.

Then there are the *Cadetten-Schulen*, which train boys entirely with a view to their becoming officers; the *Pagen-Corps*, for young noblemen exclusively, and intended to fit them for courtiers; and lastly, there are the two great schools in which all others culminate, namely, the *Polytechnikums* and the Universities. Of the latter I need say little, except that, as the home of literary and classical learning, the pure sciences are carried much further, and are more completely studied than with us; separate buildings magnificently fitted with all the most recent appliances being provided for chemical, physical, and physiological laboratories at Berlin, where men of European reputation, like Helmholtz, Hoffmann, and others, conduct their overflowing classes. But it is the *Polytechnikum* which is, or rather, perhaps, has been, the stronghold of the scientific and technical education in Germany, Austria, and Switzerland. It is here

that things take the place of words, and the true principles of nature and art, the result of scientific research, are applied to industrial pursuits. I say has been, because there are unmistakeable signs that the high-class teaching at the Polytechnics abroad will be the cause of their gradual supersession by the Universities, where the best scientific knowledge may now be obtained, though hitherto minus its special application to specific trades. And this is not surprising, because University degrees will always take precedence of those of the Polytechnics, which, however, cost the student no less labour and concentrated study to secure. The provision of new buildings, which has been so generally made at the chief Universities, has naturally followed the demand for increased scientific instruction, and the feeling is spreading in Germany that, owing to the growing importance of the *Real-Schulen*, the Universities will eventually absorb the Polytechnics, and that in future the University curriculum will be found to embrace all that formerly was the peculiar province of the Polytechnics, in addition to the pure science studies which formerly distinguished them. Our own Universities and great public schools may do well to consider this new phase of educational development. It must, however, never be forgotton that the whole general education of Germans of every grade has long been in advance of the general education of Englishmen, comprehending a wider area, and a more thorough acquaintance with every branch included. This is a factor which must always be taken into account when contrasting the relative value of English and Foreign technical education.

With reference to the extent to which manual labour is introduced into middle-class schools, Dr. Witt tells me that there certainly are workshops connected with some, if not all, Polytechnic schools, and also with most of the *Real-Schulen;* but that, of course, they are small and insignificant, as they are merely intended to give the student an idea of the work to which his theoretical knowledge shall be applied. He also states that, as a matter of fact, apprenticeships for skilled artisans exist the same as in England, though the amount of previous education required varies very much, and is generally very small;" and he adds, "My opinion is that theoretical instruction should always precede practical; if possible, they should co-exist for a while in such a manner that theory gradually yields its place to practice. In all examples I have seen of the reverse, I found the young man who considered himself practically finished, despise all subsequent instruction. I also believe that previous theoretical training facilitates his practical education by teaching him to think logically in all he does."

I may now refer to my own experiences in Germany.

The Executive Committee of the City Guilds had instructed Professors Armstrong and Ayrton to make a tour of inspection of the polytechnic schools of the German speaking countries, with a view of determining the most suitable fittings and apparatus for the new buildings then in progress at Finsbury and South Kensington. As a member of that committee, I volunteered to accompany them, and I met Professor Armstrong at the beginning of January, 1882, at Strasburg, where a new University, more fully described in Chapter III., was being constructed, to cost, when finished, not far short of a quarter of a million of money. Besides the main block of the building devoted to classical learning, mathematics, &c., separate blocks of buildings, specially arranged under the supervision of the professors themselves, were being constructed for chemistry, physics,

botany, &c. In short, it is to be a University and Polytechnic in one and the same institution, for high-class students. The architect of this princely foundation is the professor of architecture at Carlsruhe. Thither we went to find a new technical chemistry laboratory, and school of agriculture and forestry, in addition to the former buildings of the *Polytechnikum*, with museums of specimens and models of every kind. Thence to Mulhouse, a manufacture centre, visiting the model dwellings, the dye-works and calico printing establishments, and the chemical schools, established by the manufacturers. Thence to Geneva, where Professor Ayrton met us, and we, together, inspected the new University, chemical and physical schools. Thence to Zurich, at which celebrated *Polytechnikum* every science is taught, both pure and applied ; here are separate museums of models for teaching physics, chemistry, machine, engineering, architecture, drawing, modelling, agriculture, forestry, botany, &c. Here are nine professors of mathematics, 46 full professors, 54 teachers—109 in all ; 490 students, and 250 auditors—740 in all, which, however, is 500 less in number than used to attend when this school had fewer competitors of its own kind, and felt less of the growing absorption of high-class students by the Universities. (Since our visit the two chemistry laboratories described in Chapter III., have been built.) Thence to Munich, to see the splendid new *Polytechnikum* there, the new University, chemical and physical laboratories, and Pettenkofer's Hygienic Institute, concerning which Dr. Renk writes to me to say, that it also is part of the University of Munich, its Director, Dr. Pettenkofer, being the professor of hygiene at the University. It was erected in 1879, and was a part of the Physiological Institute. It is designed for the education of students in medicine and hygiene, and for practical investigations therein. Officers of health have to obtain its diploma. Thence to Vienna, where has long been a vast *Polytechnikum* for 1500 students, with a remarkable collection of models and objects for each department. Here were also new technological buidings, a new weaving and chemical school, then just opened, &c., &c. ; everywhere the provision for first-class secondary education of a technical character was extending. It has been found to give forth results which point to the desirability of this general extension.

At this stage, Professor Armstrong went on to Graz, to see the new physical and chemical laboratories there, and to Buda-Pesth, whilst Professor Ayrton and I went to Dresden and Chemnitz, Professor Ayrton returning to his London classes, after visiting Würzburg, while I rejoined Professor Armstrong at Dresden, and visited the new *Polytechnikum* there. Thence to Leipsic, in which University Professor Armstrong himself studied two-and-a-half years. Here is a street full of separate new buildings, for chemical, physical, and other laboratories. Thence we proceeded to Berlin, where, besides, the new University buildings for science, referred to before, is a large stone building, erected at the instance of local manufacturers, for special chemical analyses. There are fine laboratories attached, and students admitted, but certain of the work done is considered private to the members, and it is in fact a school of research.

Mr. Felkin has published a book on the "Trade and High Schools of Chemnitz in Saxony," to which I must refer you, where every kind of technical instruction is given, in both primary and secondary schools (a description of one of these will be found in Chapter III.).

Aachen was the last place we visited together, here is one of the finest and most

elaborately fitted Polytechnics of the many buildings we saw; it is, in itself, a lesson in technical education, of a kind of which we had then no examples in this country, not only in fitting, but in heating, ventilation, lighting, and electrical apparatus associated therewith. I spent the month of January, 1882, in making this rapid survey, and noting the fittings, the chief purpose of our visit; and an impression of preparedness, on the part of the countries we visited, to fight out the question of scientific superiority in technical matters, was left on my mind, that I should like to communicate to others.

My belief is that the omission of high-class scientific education for the middle and upper classes, in England, is the true cause of our being apparently outrun in the industrial race of the period; and the movement which is now set on foot has come from the right quarter, viz. from the commercial and manufacturing centres, where its monetary value is beginning to be appreciated.

In these schools everything is taught that can be gained at the Universities, except the dead languages, while modern languages and the applications of modern science to art and industry are added, and the thoroughness with which they are taught is best evidenced by the fact that nearly all our own leading men have found it desirable to spend some years in Germany, and they frankly acknowledge we have no such advantages in England. All secondary education in Germany is more general and more thoroughly fitted to develop scientific inquiry.

Professor Lunge, at Zurich, in answer to my queries, first, as to the difference made in teaching pure and technical chemistry in the three years' course, and secondly, as to the effect of the system upon the originality and individuality of the men turned out, writes as follows:—

"My colleague, Victor Meyer, teaches the elements of chemical science, and, further, its development in a purely scientific direction, treating the whole domain irrespective of any practical application, and merely as a science; that is, stating the facts as such, and as they occur to the chemist working in the laboratory. When his work is done mine begins. I treat only those chapters which refer to practical applications of chemistry, naturally at a greater length, and entering into a number of details on manufacturing plants, &c., which would be entirely out of place in a course of pure chemistry." [Professor Lunge was partner in one of the largest sulphuric acid and alkali works in England before he went to Zurich.] "In fact," says he, "I enter upon the various chemical industries, as such, placing the technical side foremost, but laying the principal stress upon explaining the scientific principles underlying them. I do not believe in dictating a number of recipes for dyeing, &c.; I believe that some schools in England go too far in that respect. We have always tried to keep the mean between the entirely theoretical University training, and the entirely practical course of dyeing, brewery schools, &c."

"Thus some of our students are University professors themselves now, whilst the great majority are in practical life, and very many heads of large technical establishments (in Switzerland, well-nigh all of the younger generation) have come from us. On the whole, our *Polytechnikum* (which to a great extent is the prototype of all German ones) has fulfilled its object, and sees no reason to change its principles."

In answer to my second question, Professor Lunge says:—

"During the first year, we certainly do not aim at 'individuality.' During the last year, whilst still upholding, in a general way, the course of studies for all students, we allow students to deviate from this, so as to meet their individual likes and wants, and in the laboratories we treat each of them according to his own standing, progress, and capacity. All this refers to the ordinary students who follow the regular courses. As to the auditors, we allow them from the first to specialize their studies, and treat them quite individually; but we do not like that course, except with older men coming from practice, as many men do."

Except to the extent to which mechanical work and testing materials is done in the engineering school at King's College, and at the University College, London, we found no workshops attached to any of the *Polytechnikums* which we visited. Models of every kind of mechanical action, of every kind of machine, &c., &c., there were, but these were not made by the students; in fact, manual labour is excluded from the *Polytechnikums* generally, and is only to be found in the intermediate trade schools already described, and in them to a much less extent than is commonly supposed. Now, it is true that we have no such organization in this country, but we are daily approximating to it. The influence of South Kensington is making itself felt, and our secondary schools are introducing science little by little, while great efforts have been already made in some of the chief towns in England.

For example, this has been done at Owen's College and the Grammar School, Manchester, at Mason's College, Birmingham, the Yorkshire College, at Leeds; at Sheffield, Nottingham, Liverpool, Bristol, and elsewhere.

At Bristol the famous trade and mining school, so long established there has been transferred to new quarters, at a cost of 40,000*l*., exclusive of site, &c., and is a monument of the munificence of the Society of Merchant Venturers. As their architect, I am enabled to state that no reasonable expense has been spared to render this a model school of the kind. Then, again, the realization of the complete scheme of the City Guilds will soon place London on a par with the other capital cities of Europe. The Central Institution will be an English *Polytechnikum* of the first order; the Finsbury College, a *Technikum* superior to its continental prototypes. In conclusion, what have we to learn from all this? In the first place, to support all efforts to improve the intelligence of the working classes; and secondly, to raise the standard of professional excellence.

In a paper read by Mr. Slater at the Architectural Association, the importance of the study of the natural sciences and their application to specific industries connected with the art of building, was forcibly insisted upon. Young men are too often pitchforked into the professions of engineer, architect, and surveyor, without any more relative preparedness than the working man.

Better preparation for articles of apprenticeship is the thing most wanted in the constructive professions. Apprenticeship is the best business school, but it might be improved on its educational side. The architectural and mechanical classes at the German *Polytechnikums*, which extend over three years, and the work done in which I carefully examined, is of a better class than is usually understood; from the very first, the student has to work out the strains of every floor, or roof, or speciality in construction, and to

delineate the same in skeleton diagrams attached to every plan he draws. The mechanical draughtsman is not given a subject to copy, but only the parts of a machine which he has himself to piece together, to realize the machine to be drawn, so that, from the rough sketches of the master, he has to thoughtfully work out in practical draughtsmanship the theory he has been taught to apply constructively.

True, he is surrounded with models and drawings of every mode of construction and style of design, principles of motive power, its emission, transmission, and arrest; but they are ministering spirits, not arbitrary laws, fettering his freedom. At least, they need not be other than helps to his imagination. We enter our articles at too early an age; eighteen is surely early enough, but sixteen is the common time.

The establishment of examinations at our institutes will certainly help to bring about a change in this matter, and soon it is to be hoped that, just as candidates for entry to the technical educational advantages to be obtained at the Central Institution of the City Guilds are required to produce certificates of having passed preliminary examinations at other schools of lower grade, so admission to the examinations of our professional institutes should be ultimately given only to such students as shall be able to produce similar educational certificates of competency up to a certain point, which can only be fixed from time to time, as the means of obtaining such certificates shall have been increased.

By this means, these professions will be aiding in the movement in which none can be more directly interested than they, and will prove their loyalty to our country in the best possible way, namely, that of raising the scientific tone of professional education, and fitting the students to compare with foreign competitors in the race for national predominance, in every good thing, but especially that of technical knowledge, theoretical as well as practical. As a final suggestion to aspirants to professional success, let me quote the Report of the Committee appointed by the Conference of the Society of Arts, held on the 24th of January, 1868, which states that:—

"Believing that our defects are far more due to the ignorance of those who direct works than to imperfect technical education, want of skill, or incapacity in those who execute them, the following resolutions are formulated to express our views:—

"1. For the purpose of discussion, technical education should be deemed to exclude the manual instruction in arts and manufactures which is given in the workshop."

"2. That the term 'Technical Education' is understood by the Sub-Committee to mean general instruction in those sciences, the principles of which are applicable to various employments of life."

"3. That technical instruction, as defined above, should not, as a rule, be given in separate professional institutions, but in institutions established for general education."

"4. That, with a view to the development of a system of scientific education, it is desirable that schools be established, having for their main object the teaching of science as a mental discipline. These science schools should prepare some youths for the higher courses of a college, and other less ambitious pupils for their professional pupilage."

"5. That the subject of secondary instruction, having been reported upon ably and deliberately by the Schools Inquiry Commission, the Committee do not feel it necessary to

enter into the details of this subject, while they desire emphatically to express their opinion of the necessity for the introduction of scientific teaching in all secondary schools."

"6. That it is desirable that the higher scientific instruction should be tested by public examinations, and that the proficiency of persons who pass these examinations should be certified by diploma."

"7. That the preparation for the businesses considered by the Committee is not sufficient until due scientific instruction has been followed by practical pupilage in efficient work."

"The Committee recommend employers of labour, and those in the habit of taking pupils, apprentices, and clerks, to give preference, as far as possible, to those adducing evidence of the possession of adequate instruction in the sciences applicable respectively to their professions or occupations."

Foreign Governments recognize, as I have said, the great value of higher education in science and its applications. The Agricultural School at Nancy is a striking example of this—agricultural education is much more systematic and more widely extended in France than with us. *Primary* agricultural schools are represented by the Agronomical Institute in Paris. *Secondary* ditto by the three provincial colleges of Grignon, near Versailles, of Grand Jouan, next Brittany, and of Montpellier in the south. Higher agricultural schools (one of which may be found in every department of France), are well represented by Tomblaine, near Nancy, surrounded by fifty-five acres of farm-land.

The Paris Chamber of Commerce has also instituted schools for commercial training. The earliest of which was the École Commerciale in the Avenue Trudaino. And the latest, as well as the greatest effort of the Chamber, has been the establishment of the "École des Hautes Études Commerciales," a splendid pile of buildings, with extensive grounds at the corner of the Avenue Malesherbes, costing 80,000*l.* Probably there is not in Europe a better appointed institution for giving a theoretical mercantile training.

In Russia the provision for middle-class education has proceeded rapidly during the last fifty years; in 1838 there were only fifty-six gymnasia, about 800 teachers, and 8000 pupils in all Russia. In 1880 there were 205 gymnasia, and seventy-one ordinary schools, half of which were Government institutions. In 1884 the estimates for middle-class schools were, 9,200,000 roubles. There are thirty female foundations, and over 200 gymnasia for girls, and their lecture-rooms are said to be never empty.

In the United States the relations between art and industry have been the subject of careful consideration, and Mr. Isaac E. Clarke has produced an elaborate report to the Senate on "Instruction in Drawing applied to the Industrial and Fine Arts as given in the Colleges of Agriculture and the Mechanic Arts, and in the Public Schools, and other public Educational Institutions in the United States." In the words of the concluding paragraph of the Introduction to this Report, the objects in view are summarized thus: "Finally,—to urge the practicability and advisability of introducing industrial art education throughout these United States;—to show the intimate relation of this movement to the prosperity of a manufacturing people, and to enumerate the resources and instrumentalities now available in this country for the development of industrial and high art; sum up in briefest words the purposes and contents of this Report."

In the October, 1886, number of the *Engineer*, the subject of technical schools in the United States is considered. It is there stated that technical education is a subject which each year attracts an increasing amount of attention from the thinkers of all civilized countries, and it is broadly asserted that, other things being equal, the best technically educated nation must eventually become the wealthiest and the most powerful. As an illustration, the United States are alive to this, and are rapidly extending and developing technical education. A summary is given of an interesting paper on "Technical Training at the Worcester County Free Institute of Industrial Sciences," read by Mr. G. J. Alden, of Worcester, Mass., before the American Society of Mechanical Engineers, in 1885. The article concludes with the following important suggestion;—"We can only add now, that we believe the time is approaching—if, indeed, it has not already arrived—when a regular codification of the systems of *teaching the higher or professional*, as well as the working branches of mechanical engineering must be effected, and some such method as that suggested by Professor Webb, in the discussion which followed the reading of Mr. Alden's paper, be adopted." He said, "There are really three kinds of schools which at the Philadelphia meeting of the American Association I suggested, and which were simultaneously proposed by General Walker at the Social Science Association. *First*, a school of mechanical engineering, where the object is to produce the engineer who must know all the higher parts of the business. *Secondly*, we have the School for Superintendents, who must be able to direct and control the workmen, and must know intimately all the processes; he does not need to know the higher parts, for which he can depend on the engineer. *Thirdly*, we have a third kind of school, which is for the younger students who have not yet chosen their business or profession, and the majority of whom will never engage in mechanical pursuits, in fact for all boys who are in public schools. This is called 'The Manual Training School.'"

In the third chapter of this book will be found a description of the two latest and best engineering schools in England, that of Professor Unwin at the Central Institution in London, and of Professor Barr at the Yorkshire College. Further information on engineering colleges will be found in Professor Kennedy's paper on this subject, and the discussion thereon, read at the Institution of Civil Engineers in December, 1886.

Since writing the foregoing, representative men like Sir Philip Magnus, of London, and the late Professor Fleeming Jenkin, of Edinburgh, have expressed their views on the character of the education required for the future. Sir James Reed has urged the value of technical education in naval architecture, and in May, 1886, Mr. Churton Collins wrote a letter to the *Pall Mall Gazette* on the importance of science studies in completion of a liberal education.

Sir Philip Magnus considered that "the whole question bristled with difficulties, and the views of one set of professors were diametrically opposed to those of another set. As Professor Perry had pointed out, the problem of giving technical instruction to masters or superintendents was by no means so difficult as that of giving instruction to the hands who were to work; but he might express a hope that even that problem would become much easier than it was at present, for the simple reason that, after a time, they would not require to instruct working men, inasmuch as they would have already instructed in their youth those who were to become working men. But even when the problem was reduced to that of

instructing apprentices, it was not without difficulty, and the most conflicting views existed upon it in different parts of the continent. France was moving in one direction and Germany in another. In the City of London they had endeavoured to find a solution, if only a temporary one, in the direction which he thought was a correct one, of giving evening instruction to apprentices. This system harmonized with the habits and customs of Englishmen; and a system which might be adapted to the sunny climate of Italy, might not possibly be adapted to our more cloudy skies. The temptation to walk about and amuse oneself in the evening was much greater in a beautiful climate; and here we could avail ourselves of the general desire of young men to be under some sort of cover during the evening, to impart to them that instruction which would be useful to them in their daily occupations. There seemed to be a general consensus of opinion that manipulative skill could only be acquired in the workshops, and that what was needed was to supplement that practical skill by theoretical instruction given in the evening or at some appropriate time. It was the custom in many parts of Germany to give this instruction on Sundays, as well as in the evenings of other days; but that would probably be distasteful to the people of this country. With regard to higher education, there was a great conflict of opinion abroad as to the respective advantages of a University or *Polytechnikum* training for giving the requisite knowledge to those who were to become the managers of industrial works. But prior to this question, was another, viz. what was the best training for a young man intended to take the lead in a manufactory, before entering the University or *Polytechnikum?* Here again, their German advisers were by no means at one; they had established the *Real-Schule*, and on the other hand, the *Gymnasium;* in the first, science, mathematics, and modern languages were taught; in the second, the old grammar-school curriculum was followed. Then it seemed to the German educationalists that something between the two was wanted, and so they established a *Real-Gymnasium*, where part of the classics was done away with, and a little mathematics and drawing were added. Even this did not quite satisfy them, and now they were considering whether they should not establish something between the *Real-Gymnasium* and the *Gymnasium* itself. Into these perplexities he (Sir Philip) would not enter, but there lay at the bottom of all this, a very important question, whether, after all, the old classical training was, or was not, the best preparation for those who were afterwards to be educated in the higher branches of science, and though the opinion was opposed to his own, he must say that there was a large number of scientific professors in Germany who were inclined to think that the old classical training was the best. What naturally occurred to one on hearing a view of this kind, was that possibly science was not so taught in the German schools as to yield that amount of mental discipline which could be obtained by a study of the classical languages. The classical languages had been made the instrument of education for centuries, whilst the teaching of science was comparatively new, and it was quite possible that the majority of teachers, both in Germany and England, were not sufficiently skilled in pedagogic principles, to enable them to fetch out of scientific instruction that mental gymnastic, and discipline which, after all, was the object and end of all secondary education. On the whole, he (Sir Philip) did not think the course which was being followed in England was very far wrong. Whilst some of the best minds were

busily employed in considering what were the best methods of instruction for different classes of persons, those for whom the instruction is intended did not always seem sufficiently alive to its importance. If part of the energy of those who were elaborating schemes of education were directed to showing the importance of instruction, and not only the importance, but the difficulty of discovering any royal road to knowledge, they would be doing a very great thing. In this country people were too anxious to arrive rapidly at results, to take a third year's course before the first; in Germany this was not the case, and the students were too willing to go through a regular organized course of study. In England, education left off at too early an age, both for the workmen and the masters; and in discussing any scheme of instruction, the period over which it was to last was a most important element to be taken into account in arranging the curriculum itself. It was most necessary to impress upon all who desired to take advantage of any system of education, that time was an essential element, and that they must devote to the training for any profession a longer time than had hitherto been the custom. There were many problems in technical education yet remaining unsolved; one was the degree, if at all, to which manual work should be introduced into primary or secondary schools. They knew what was done in this way in France, and that very little was done in Germany. Another unsettled question was the relative advantages of apprenticeship schools, such as existed in France, and of the combined system to which he had referred, or work by day and instruction in the evening. Then as regards secondary instruction, there was the whole question of the value of science teaching, to which he had referred. Germany was looked to as the country in which science teaching was principally carried on, and yet a very eminent professor of chemistry in Germany had told him, that he regarded it almost as nonsense to introduce chemical laboratories into secondary schools; it was quite sufficient for the pupils to receive instruction in the general principles of their science, the practice came soon enough. Those engaged in these experiments were giving their best thoughts to the question; and he (Sir Philip Magnus) believed, that before many years there would be elaborated throughout the kingdom a system of higher scientific and technical education, which would favourably compare with any to be found in Europe."

The late Professor Fleeming Jenkin, F.R.S., remarks that "establishments like King's College, University College, the Scotch Universities, the Victoria University, and similar institutions in Liverpool, Dundee, and elsewhere, were proceeding from well established and accepted lines, but they wanted, especially the older ones, more funds. They had one professor teaching two or three hundred students, instead of twenty or thirty men, as was the case in Germany. It was in teaching power for the upper and middle classes that Germany was so superior to England; but we could not simply copy Germany; the whole social arrangements were so different that that would be impossible. We ought to attain the same end by means specially congenial to ourselves. The question of the *Gymnasium* as compared with the *Real-Schule* was a very curious and interesting one. About twelve years ago he (Professor Jenkin) travelled in Germany, and found the opinion prevailed that the pupil who had been trained upon the humanistic studies ultimately beat his competitor in scientific work. If that were a necessary effect, it ought to be taken to

heart, and they ought not too hastily to insist on the abolition of the dead languages as a means of training. The explanation which commended itself to his mind was, not that scientific teaching was really inferior as a means of mental discipline, but that it was much more difficult at present to find in Germany or in England, men who were capable of using scientific teaching in that way, and he much feared that it would always remain so. For this reason, Latin and Greek were dead languages and did not change; they were taught now as they were fifty years ago, but science changed with inconceivable rapidity, almost from day to day. What were the first-fruits of science last year were already antiquated, and the difficulty was how to get a body of teachers who could follow all these constant changes at the same time that they were imparting instruction in secondary schools. He did not say it was impossible, but there was a great difficulty. After all, the personal influence of the teacher was of immense importance, perhaps quite as much so as the subject-matter taught; and if you had a man of broader culture and greater force of character teaching Latin than the man who taught science, Latin would prove the better preparation for life. On the other hand, if the man who taught natural philosophy was the better man of the two, the boy who studied natural philosophy would probably turn out the better man; and, really, in entering on special work, the character of the lad mattered more than the specific information he had acquired up to that time. As far as the higher education went, therefore, he (Professor Jenkin) thought the main thing was, not the introduction of a little science along with Latin and Greek, but the establishment of several great scientific colleges where the professors should be first-rate University men—enthusiasts, who believed there was nothing in the world like science, and that they would turn out men superior in every respect (including cricket) to the men from the old-fashioned schools, where they learned Latin and Greek. They would never get what they wanted while science was relegated to what was called the 'modern side,' and treated with more or less contempt. But while we had something to learn from the Continent in the matter of this higher education, with regard to the education of the artisan, which was of equal importance, nothing had been done in any part of the world whatever, except of the most rudimentary kind. His impression was that this would appear by the Report of the Royal Commission. He could find nothing on the Continent twelve years ago, and though something had been done at La Villette, notwithstanding the eloquent picture drawn by Mr. Lucraft, he greatly feared it would be absolutely impossible to provide school training for the hundreds of thousands of working men in all the numberless subdivisions of their trades. If there were others who took a different view, let them try by all means, and see how their scheme would grow. That was the real test in England; everything that had organic vitality would grow and develop. They all agreed that the work could not be done by the Government. He held very special views upon this subject, which it would take some time to develop; and he would only say generally that he believed that the education of the workman could be greatly improved by a systematic supervision of the manner in which work was done in the workshops themselves; and that this supervision might be carried out by the co-operation of the employers and the men. This might seem a very Utopian scheme, and he (Professor Jenkin) could not explain the details by which he thought it might be worked out, but they would all agree that there existed in this country

the material for giving the best technical education in the world, and, therefore, all that was required was organization. Instead of the workman being left to himself or to the tender mercies of capital, he should be guided, superintended, and rewarded; but this superintendence and organization could not be carried on from without, but must be undertaken by those who were personally interested in the matter, and who had specific knowledge of the trade itself."

These opinions are of considerable interest and value, yet it is not my intention to follow up the questions raised any further, but merely to remark that the universal opinion is that, since the competition between nations is increasing every day on the question of the quantity and quality of technical education to be given in the future, therefore its national importance must be admitted, and can hardly be over-rated. It is perfectly true, as Professor Perry remarks, that those who did not take advantage of Technical Education when they might, deserved no pity; but my object has been to see whether the information I have collected would throw any light on the cause of the great difference which seemed to exist, in the amount to which technical knowledge had been a source of profit to one country more than another. The difference in primary education did not seem to give the clue, but when I examined the provision made in foreign countries for higher education of a scientific kind, I found something so superior to anything in England, that I thought a lesson might be learned from it. Whatever was done for working men, there must also be something done for those who might help themselves and did not, to make the difference between England and foreign countries less perceptible than it now was. I do not care to say much as to the disadvantage of an exclusively classical education, but I do feel that if Latin and Greek are dead languages, and no new life is to be got out of them, exclusive preference for them is not all that is required for the expansion of men's minds. On the other hand, that which is growing every day so fast that there are not capable teachers forthcoming to teach it, must have within it a fund of intellectual activity, far in advance of anything to be got out of a dead language. But the comparison does not lie between dead languages and science subjects only, but also between them and modern living languages, and it would be interesting to know if those "trained upon the humanistic studies," who are said to have "beaten their competitors in scientific work," would have been equally successful if opposed to scientific men, proficients also in modern languages, as it is contended they should be, at least in French and German.

CHAPTER II.

ANALYSIS OF THE SECOND REPORT OF THE ROYAL COMMISSIONERS ON TECHNICAL EDUCATION.

I HAVE already referred to the *First Report* of the Royal Commissioners, but since the previous chapter was first written, the *Second Report,* which I now propose to briefly review, has been published, treating of the whole subject of British and Foreign Technical Instruction in a remarkably clear and exhaustive manner.

The First Report dealt with primary schools only; the Second embraces the whole system of applied science and art teaching from the elementary schools to the great Universities. It is arranged in five parts.—Part I. comprises "*Technical Education on the Continent,*"—and opens with an interesting introductory account of primary and secondary schools in France, Switzerland, Germany, Austria, Belgium, Holland, and Italy—which is followed by a critical examination and general description of "*Special Trade and Technical Schools abroad.*"

The approximate divisions under which this subject is discussed are:—

I. *Evening schools available for artisans,* thus—

1. Evening instruction in France, particularly art classes. 2. Evening schools in Switzerland. 3. In Germany. 4. In Austria, particularly the turners' and jewellers' classes. 5. In Belgium, specially the art schools at Molenbeek, of St. Josse, and Ixelles. 6. In Holland. 7. In Italy.

In the general view given of these Continental evening schools, and following their particular description of the same, the Commissioners draw attention to the *Continuation* schools of Germany and Switzerland. In Bavaria, Baden, and elsewhere, pupils leaving the primary schools, at the age of thirteen, are compelled to continue their studies in the evening schools till the age of sixteen; and they wisely remark that for the want of such evening instruction, apprentices find themselves too ignorant to avail themselves of the special technical instruction which they have the opportunities of obtaining in the workshop, and on this account, and also because they serve to give the youth a taste for study at the time when he begins to feel the value of such instruction, these schools

have proved to be most serviceable to German and Swiss artisans in quickening their intelligence, and in affording them useful information bearing upon their trades.

Still it is gratifying to know that in the opinion of the Royal Commissioners, as regards evening *science* teaching, there seems to be nowhere in Europe any organization for systematic evening instruction comparable, as regards the number of subjects taught, and the facilities afforded for the establishment of classes, and for the examination of the student's work, with that undertaken by the Science and Art Department in this country, and recently supplemented, in the applications of science to special industries, by the City and Guilds of London Institute for the advancement of Technical Education.

II. The second general division treats of "*Artisans' General Technical Schools and Apprenticeship Schools.*

1. Apprenticeship schools in France, such as the school of the Rue Tournefort, Paris, the school of La Villette, Paris, the Havre Apprenticeship School, and the Watchmakers' School, Paris. 2. The apprenticeship schools of Switzerland. 3. Of Germany. 4. Of Austria. 5. Of Belgium. 6. Of Holland. 7. Of Italy.

After describing above a score of these schools, the Commissioners quote the opinions of Mr. Fenton, the first secretary of the legation at the Hague, who was secretary of the legation at Munich at the time of the building the first great Polytechnic school of that city, and who on three occasions reported on Technical Education in Bavaria. Mr. Fenton said that but a few years before, there was no workshop teaching in any of the schools of that country. It was then considered that it was no business of the school to trench upon the province of the workshop; but he believed that the views of many educationists were becoming somewhat modified on this question, and that they were finding the workshop could help the school, just as the school could help the workshop. In the same way as the laboratory illustrates the principles of chemistry, so the actual machine or mechanical operation often illustrates the principles of mechanics, and in each case the student without practical illustrations would less rapidly acquire the knowledge he seeks.

With regard to the comparison between English and Foreign workmen, Mr. Fenton states that, after a long experience of the Continent and close observation in several countries, he has found no workmen comparable with the English, and if the English workman, with his physical strength and force of character, would cultivate his intelligence, he would still further distance the foreigner.

Mr. J. Diefenbach, the representative of the Education Department of Wurtemberg at the exhibition at Nuremberg, states that there are no workshop schools in Wurtemberg like the apprenticeship schools of Paris, or the industrial schools of Bavaria; but evening schools, similar in many respects to the *Fortbildung* schools of other German States, are established everywhere in Wurtemberg. The curriculum is arranged to suit the wants of the apprentices and workmen in each locality. The boy leaves school at fourteen and becomes an apprentice till eighteen. During his apprenticeship he attends the *Fortbildung* school, which supplements his earlier education in ordinary literary subjects, and teaches him the sciences bearing upon his trade, and drawing. Mr. Diefenbach stated that his Government was of opinion that for securing the permanent prosperity of the State, the most im-

portant education is that of the artisan. The work of the world is done by him, and that nation which best educates the artisan will excel in industry and manufacture.

III. The third general division relates to "*Intermediate Technical Schools for Foremen and Technical Managers.*"

These are divided into (1) general technical schools, (2) weaving schools, and (3) industrial art schools. The first division is again subdivided into (*a*) higher elementary technical schools, (*b*) secondary technical schools, and (*c*) building, engineering, and mining schools. The Commissioners assert that in the higher elementary technical schools of the Continent the children of artisans and small shopkeepers are able to obtain an education which is technical in so far as their studies are specially directed towards the requirements of commerce, mechanical or manufacturing industry. Mathematics, science, and drawing constitute the main subjects of instruction. In nearly all the modern French schools, of which that at Rheims may be taken as the best type, the laboratories for the teaching of practical chemistry leave little or nothing to be desired. Workshop instruction is carried to a much more advanced stage than is possible or desirable in the elementary schools, and there are special departments, replete with models, apparatus, and specimens, for teaching the technology of the trades which form the staple industries of the district in which these schools are situated. *The classical languages do not enter into the curriculum of any of these schools.* The time thus saved is devoted to mathematics and modern languages. Schools of this kind are singularly wanting in our own country.

In the *Continental Secondary Technical Schools* referred to in sub section (*b*) the majority of those who are to become managers and sub-managers of industrial works receive their training, which is completed by their nineteenth or twentieth year. Thirteen of these schools are described.

In reference to the *Continental Weaving Schools*, fourteen of which are described, the Commissioners state that in their opinion the most important schools of this type are that of Chemnitz in Saxony and the spinning and weaving school of Mulhouse. The weaving and dyeing school at Roubaix is about to be displaced by one of the most complete schools yet erected, at a cost of about 80,000*l.*

Of the schools fulfilling the higher object of teaching design, in which departments of pure art exist, although in other respects not to be compared with such schools as the one at Chemnitz, the Commissioners noted the weaving and dyeing schools of Biella and Como in Italy, the school of design and weaving at St. Etienne in France, and, transcending in importance all these, the weaving and dyeing schools of Vienna, and of Crefeld in Rhenish Prussia, which may be cited as good examples for English imitation.

In regard to the *Continental Industrial Art Schools*, as at Munich, Nuremberg, Dresden, Berlin, Vienna—fully described—the Commissioners are of opinion that the dignity of the designer's work, and the importance of the position he occupies is not sufficiently acknowledged in our own country. If the honour we pay to painters and sculptors were even in a lesser degree given to "artistic designers," they would soon take their proper rank in this country. The best training for each, during the first few years of his career, is drawing, modelling, and painting. Not until he is thoroughly master of the various materials and processes by which art is capable of expression, and of the influence of style in the develop-

ment of the fine arts, can the student do any good by concerning himself with the varieties of design and the application of the same to industry.

It is at this later period of his training when the designer can be materially benefited by placing before him well-selected illustrations of what the best designers and art-workers of previous periods have achieved ; and it is here where the influence of industrial museums, collections of patterns and drawings, and exhibitions of art workmanship may exert a most powerful influence for good on the young designer.

IV. The fourth general division comprises " *Women's Trade and Professional Schools,*" as developed in France, Germany, Austria, Belgium, Holland, and Italy.

These are intended generally for the daughters of small shopkeepers and of the upper class of artisans, and in most of them the primary education of the children is continued and supplemented by instruction in one foreign language and in drawing in addition to the special technical teaching which they provide. The Commissioners report that whilst needlework and dressmaking form the principal subjects of instruction in nearly all these schools, book-keeping, the elements of law, and commercial correspondence are taught in many of the schools of France, where young women are more frequently employed as accountants and overseers in commercial houses than is the case in other countries.

In both Germany and Austria, where women are more commonly employed in domestic industries, the technical instruction is almost entirely confined to plain sewing, embroidery, dressmaking, millinery, laundry work, and cooking.

In Belgium, Holland, and Italy the education in women's trade schools embraces a wider range of subjects, and includes artificial flower making, lace designing, painting on fans, on porcelain, and on glass, typography, telegraphy, and pharmacy.

In all these schools great attention is given to drawing, as underlying all the industries in which special instruction is given. Nine of these schools are described.

V. The fifth general division is devoted to the review of " *The Higher Technical Instruction for Employers, Managers, &c.*"

These schools comprise (1). École Centrale, Paris ; (2). Polytechnic School of Paris, and the higher schools of France ; (3) the Polytechnic Schools of Zurich, Munich, Vienna, Stuttgart, Dresden, Hanover, Carlsruhe, Aachen, Berlin, Delft, and Moscow, and the Mining School of Freiberg in Saxony.

The schools in this third section have cost not less than *three millions sterling*, and are maintained at a cost of 200,000*l*. per annum. With regard to the nature of the teaching given, the Polytechnic School at Zurich may be taken as an example.

This institution comprises seven special schools :—

1. The Architectural School, with three years' course.

2. The Civil Engineering School, with three and a half years' course.

3. The Mechanical Engineering School, with three years' course.

4. The School of Chemical Technology, including pharmacy, with three years' course.

5. The School of Agriculture and Forestry, forming two sub-sections, with a two and a half years' course.

6. The Normal School, destined to educate special teachers for mathematics and natural science, also forming two sub-sections.

7. School of Philosophical and Political Science.

Upwards of 200 distinct courses of lectures are given by the forty-five professors andtheir thirteen assistants.

The fee for a complete course of instruction in any one department is but 4*l*. The total cost to a student in the chemical department, including laboratory practice, is less than 12*l*. per annum.

An important feature of the Institution is the number and variety of the laboratories libraries, museums, and collections of apparatus and objects of scientific and artistic interest, which it possesses—in all twenty-two in number. In common with the Polytechnic schools of Germany, there is no manual instruction in workmanship of a mechanical character.

Speaking of the influence of the Zurich Polytechnic School, the Commissioners remark that this renowned school, established in 1854, has from its very commencement endeavoured to impart the greatest possible extent of scientific instruction in each of its departments, and its efforts have been to direct thought and research of the highest kind in their applications to industrial pursuits, and thus to bring about the necessary mutual interchange of ideas between science and practice; and it has been so far successfnl that students have come to it from all parts of the world, many of whom are now holding important positions in various industrial establishments which the Commissioners have visited.

Professor Zeuner, of the Dresden Polytechnic School, states that the main object of Polytechnic instruction in engineering is to make the students acquainted with the scientific principles underlying the construction of machines and engineering works, and to enable them to understand and appreciate every new invention or discovery when it comes before them, and with this object all inventions involving new principles are brought under the notice of the students and discussed by the professor.

As regards the influence of this instruction on the industries of the country, Professor Zeuner considered that the whole mechanical industry of the Germans was the result of the superior education of the people; that whereas, formerly, they purchased locomotives from abroad, they now use exclusively those made in Germany, and that all their great industrial works—such as Krauss' of Munich, and Kesler's in Esslingen—were filled with Polytechnic students occupying posts of managers, directors, &c.

The professor, while recognising the ability and skill of German engineers, freely acknowledged his indebtedness to the works and influence of Rankin, who is regarded as the greatest authority in mechanical science in all the chief engineering schools of Germany.

The Royal Commissioners in their general review of Polytechnic schools quote the opinions of many of the more distinguished professors as to the value of the training at these schools, as compared with that given at the Universities, and especially how far the division into purely scientific subjects as taught in the Universities, and applied science as taught in the polytechnic schools of Germany, is a wise or advisable arrangement, and what is the best preliminary training for Polytechnic students.

Professor Hofmann and Dr. Quincke of Berlin, Dr. Victor Meyer of Zurich, Professor Fick of Wurzburg, and Professor Kühne of Heidelberg—all think that the Gymnasium training for the Universities serves equally as well for the subsequent studies of the Poly-

technic as the instruction of the Real-School. But Professor Lunge, of Zurich, who was for many years resident in England, when he was the manager of large alkali works, holds, with regard to the preparatory training of technologists, an opposite view to that of Professor Hofmann and the rest, and his views are shared by an equally eminent authority, Dr. Wislicenus, of Wurzburg. Dr. Lunge holds that the linguistic training of the German Gymnasium is unsuited as preparatory to a technical career, inasmuch as the time there devoted to mathematics, drawing, and modern languages, as well as the elements of natural science, is wholly insufficient; and he therefore inclines to the opinion that the education given in the Prussian *Real-Schulen* of the first rank is distinctly preferable to the purely linguistic system of education of the Gymnasium proper. The Royal Commissioners seem to be in accord with Professor Lunge, and give some arguments in favour of the system which the Germans have adopted; and, with regard to the general diffusion of scientific education and its results, they say that to the multiplication of these Polytechnics, and to the small cost of higher education, may be ascribed the general diffusion of a high scientific knowledge in Germany, its appreciation by all classes of persons, and the adequate supply of men competent, so far as theory is concerned, to take the place of managers and superintendents of industrial works as well as of teachers in technical and other schools.

They truly say, that in England there is still a great want of this last class of persons; and whether schools of practical and applied science be affiliated to the University or exist separately and independently as in other countries, it is very important that facilities should be offered to such selected pupils from schools of lower grade as may be competent to profit by them, to receive the highest scientific and technical instruction, gratuitously or at a small cost, in order that this country may be better supplied than it is at present with competent instructors.

This is the view taken by Professor Huxley and other educational authorities, and it is that which the City and Guilds of London Institute is working out at the Central Institution, South Kensington.

The vast congregation of facts in the detailed description of the numerous continental schools referred to, is supplemented by remarks of an extremely valuable character, resulting from the habit of the Commissioners of testing the value of the technical education given and received by the inspection of various manufactories and workshops and business laboratories.

Thus the chapters on "The Influence upon Industry of Institutions of Scientific Research," also "The Influence of Technical Instruction on certain Branches of Chemical Industry,"—as for example: the chemical colour industry of Germany and Switzerland, the manufacture of beetroot sugar, the alkali manufacture,—are papers of great import. It is, however, satisfactory to know that the foreigner with all his advantages of scientific education, is not a better alkali maker than the Englishman; but it must be remembered that many foreigners are employed in England. The Commissioners remark that it certainly cannot be said that the English soda industry suffers in comparison with that of the Continent, owing to the want of scientific knowledge on the part of those who conduct it. Men of the highest talent, and most eminent for their scientific knowledge, are found in all our large alkali works, and it has even been attested that, with one or two exceptions

everything in the way of important improvements in the alkali manufacture by the Leblanc process has originated in England.

This fifth general division of the Report concludes with a review of the *Continental Art Schools, Galleries, and Museums.* The question of providing museums of art and industrial objects for provincial towns, is still almost in its infancy in this country. And though Birmingham, Liverpool, Nottingham, and recently Manchester, have established promising art galleries, and in other large towns also some interesting collections exist, there is as yet, in the opinion of the Royal Commissioners, no provision of this sort at all comparable with the amply furnished museums and galleries possessed by many provincial towns on the Continent, especially in France. It cannot be disputed that to the influence of these collections, and to the direct bearing they have on art and industrial training, is due much of that abundancy of art resource which is so advantageous to many French industries and manufactures.

The porcelain painting of Nantes, and the glass painting of Angers, owe very much to the direct teaching of their art schools, and to the admirable illustrative collections they possess.

It may be broadly asserted that every French provincial capital possesses not only an efficient school of art, but a picture-gallery and museum either of industrial or antiquarian interest, and also a good library. Nor is it found that these influences tend mainly to the creation of picture-painters. That department of art is not specially encouraged, the main function and utility of their art-teaching being in its application to local trades and industries.

Professor Lange, of Munich, and Professor Mayer, of Nuremberg, gave to the Commissioners important information as to the working of the art schools of Bavaria and their effect upon the industries of the State. The professors stated that the conviction is universal throughout the country, that the various art and technical schools are exercising a most important influence upon their manufacturing industries. In their belief, they can only meet the competition of their rivals, in their own and other countries, by training their workmen in taste and skill, and their industries will prosper in proportion as they keep up the efficiency of their schools and spread their influence among the workers themselves. On all hands this movement is progressing, and they are compelled to strain every nerve in order not to fall behind. And what is the result? They can see a superior taste in every object made by hand, as an outcome of these schools; and they can now almost tell by the work where the workman or designer has been trained. Taste has become almost like a man's handwriting, and they can recognise the man, or, at least his school, in his work.

With reference to the *Apprenticeship System*, the professors stated that modern civilization had almost crushed it out; in olden times every workshop was a school, and the "Werkmeister" was an artist as well as a handicraftsman.

The apprentice went through his course of seven years' apprenticeship and learned every detail of his master's business. All this is now changed, the workman is ceasing to learn his trade in his working hours. It is, therefore, all the more important that the school should step in and supply, as far as possible, the defects of our industrial system.

These art schools represent the faith of the people, expressed on all hands and supported by daily experience, that taste is one of the most important factors in industry. It is not now a mere sentiment that prompts governments and municipalities to make great sacrifices for these schools. They feel that the prosperity of their industries depends entirely upon the cheapness and attractiveness of their productions, and, although the workshop may do something for the former, the latter depends upon the taste and skill of the employer, foreman, or artisan.

Professor Ewald, of Berlin, said that art education was at a low ebb in Berlin, and as to the methods of teaching applied art, he made the following pertinent remarks. " In the training of a designer, the most important task of the teacher is to ingraft in the student's mind a knowledge and love of pure art, which forms the basis of all applied art. Teach drawing, or art pure and simple, in the first instance, without heeding the predilections of the student, because the more thoroughly students are grounded in the knowledge of form, colour, &c., the more proficiently will they be able to turn their knowledge to useful account afterwards, and the less likely will they be to be led astray when they have to apply artistic principles to industrial purposes. For workers in wood, stone, and the decorative arts, it is impossible to attach too great an importance to modelling."

The Royal School of Art, Berlin, to which Professor Ewald is attached, has trained many successful designers, who are distributed over a number of manufactories in the city and in other places, and designs made by students attending the school are often sold to manufacturers. As to the separation of the school from the workshop, Professor Ewald was of opinion that, where art manufactures are in an advanced state, the application of art industry may safely be left to the workshop. Given your artistic student, whether intended for a designer or a workman, the workshop will give him all the opportunities necessary for the application and exercise of his knowledge, and he will find new ideas and inspiration from sources of his own selection, and apply them in his own way; but when taste is low, and manufactures are undeveloped, he thinks it justifiable for the State, not only to teach art, but also its application to manufactures. He would, therefore, teach drawing in all schools, carry it forward to as advanced a stage as possible in the direction of designing, and would then apply it, as at Munich and Nuremberg, to the actual work to be done.

The great art schools of France and Belgium are admirable institutions, but, as examples for England, they present features to be avoided as well as to be imitated; and with regard to the national characteristics of French and English, one gentleman remarked to the Commissioners that, from his large experience of foreign nations, he had come to the conclusion that race and blood have great influence upon the handicrafts of a nation.

The French are more elegant than the English, altogether apart from education, and their designs are characterized by greater elegance.

In Paris the designers are surrounded by examples and aids to inspiration such as cannot be found elsewhere. Paris, to use a commercial term, may be called "the exchange" for designers from all parts of Europe, and it is the principal market for designs.

The drawing of the Parisians is generally of a decorative character, and in freedom of outline they excel all other countries.

Part II. of the Report is entirely devoted to a description of visits to forty-seven of the *Industrial Establishments on the Continent* in France, Switzerland, Germany, Belgium, and Italy.

Part III. details *visits to various Technical Educational Institutions in the United Kingdom*—in London, Oxford, Cambridge, Manchester, Liverpool, Oldham, Barrow-in-Furness, Birmingham, Leeds, Sheffield, Bradford, Keigh'ey, Saltaire, Nottingham, Bristol, Bedford, Kendal, Glasgow, Edinburgh, and Ireland,—comprising nearly a hundred institutions. This list is fairly complete, though it is not presented as such. It gives, however, an approximate view of the educational resources of the country in the direction of applied art and science to the day of the Report, and our progress in the future may always be contrasted with this *résumé* of our achievements up to the period under discussion and review. The description of these various institutions is interspersed with most valuable comparisons and criticisms as the occasion gives rise to the remarks, and this imparts a lively interest to the Report generally, because social and economic questions are discussed as well as scientific, artistic, and commercial interests.

Part IV. gives the conclusions arrived at by the Commissioners, and closes with their general recommendations and suggestions. The Report is contained in the first volume, and has an appendix, being a special report on *Schools for teaching domestic trades in South Germany and the Austrian Provinces.* The second volume gives the report of Mr. Jenkins on agricultural education, and of Mr. Mather on America and Canada. Volumes III., IV., and V., give the interesting evidence of the remaining appendices.

The conclusions arrived at by the Royal Commissioners, as set forth at the end of their Report (Part IV. of Volume I.), commence with a brief review of the progress of manufactures abroad, especially in new chemical processes, in the ventilation of mines and sinking of shafts, in turbines for utilizing water power, in dynamo machines, in the economical construction of roofs and bridges, in calico-printing, in dyeing silk and woollen fabrics, in woollen yarns and other new textile industries,—much of that success being due to more painstaking, more pliancy, and greater thrift; and also to the general cultivation, the knowledge of modern languages and of economic geography, usually possessed by Continental manufacturers.

But, great as has been the progress of foreign countries, and keen as is their rivalry with us in many important branches, the Commissioners find no hesitation in stating their conviction, which they believe to be shared by Continental manufacturers themselves, that, taking the state of the arts of construction and the staple manufactures as a whole, the English people still maintain their position at the head of the industrial world. They say, "Not only has nearly every important machine and process employed in manufactures been either invented or perfected in this country in the past, but it is not too much to say that most of the prominent new industrial departures of modern times are due to the inventive power and practical skill of our countrymen. Amongst these are the great invention of Bessemer for the production of steel in enormous quantities, by which alone, or with its modification by Thomas and Gilchrist, enabling the commonest description of iron to be used for the purpose, steel is now obtained at one-tenth of the price of twenty years ago;

the Weldon, Hargreaves, and Deacon processes, which have revolutionized the alkali trade; the manufacture of aniline colours by Perkin; the new processes in the production of silk fabrics by Lister; the numerous applications of water pressure to industrial purposes by Armstrong; the Nasmyth steam-hammer; the compound steam-engine, as a source of great economy of fuel; and the practical application of electricity to land and submarine telegraphy by Cooke, Wheatstone, Thomson, and others."

The adoption by our Continental neighbours of English models of machinery, of power looms, iron and steel ships, and their appreciation and use of our technical illustrated journals, and of our art manufactures in porcelain, earthenware, glass, and decorative furniture, show, the Commissioners think, "that the origin or initiation of modern industrial systems is due in the main to Great Britain, so that when, less than half a century ago, Continental countries began to construct railways and to erect modern mills and mechanical workshops, they found themselves face to face with a full-grown industrial organization in this country, which was almost a sealed book to those who could not obtain access to our factories."

"To meet this state of things," say the Commissioners, "foreign countries established technical schools like the École Centrale of Paris, and the Polytechnic Schools of Germany and Switzerland, and sent engineers and men of science to England to prepare themselves for becoming teachers of Technology in those schools.

"Thus it comes to pass that Technical High Schools exist in nearly every Continental state, and are the recognized channels for the instruction of those who are intended to become the technical directors of industrial establishments." And if we are to retain the supremacy we had achieved, we must supplement our system with some of the educational appliances which have proved so successful abroad.

Having pointed this moral, the Commissioners proceed to notice the technical knowledge of foreign manufacturers, and to show that the establishment of the Polytechnic schools was soon followed up by the creation of technical schools for foremen, and intermediate gratuitous French schools. The French and German schools for miners and workers in iron and steel are next noticed, and trade and other societies' efforts as teaching bodies; the Sunday classes and home industries; and they draw attention, not only to the more generally diffused primary instruction, but the better education of artisans abroad as respects drawing and applied art.

The Commissioners then proceed to consider the growth of technical education in this country, which they believe is now generally acknowledged to be necessary to do ourselves justice, and to maintain the high position already attained.

They refer to the special schools established by manufacturers and large employers of labour, like Sir William Armstrong's at Elswick. The reorganization of the Mechanics' Institute, as at Manchester and elsewhere. The classes established by the leading co-operative societies, and the teaching of the natural sciences at our ancient Universities. The influence of schools on industries is already great; without the Lambeth School, the art productions of Messrs. Doulton could scarcely have come into existence. The desire to ascertain the best modes of advancing technical instruction was most encouraging to the Commissioners, in whose opinion the foreign system of technical instruction was not applicable without modifica-

tion; and they bear testimony to the intelligent and able administration of the science and art classes at South Kensington, which as a system of instruction for the great body of our foremen and workmen, though susceptible of improvement, was in its main outlines not desirable to disturb. The best preparation for technical study they consider to be good modern secondary schools, of which many more are required, and they suggest that legislation is required to supply this greatest defect in our educational system. Scholarships from elementary schools should give easy access to secondary and technical schools for the more promising students, and more science teaching should be introduced into elementary schools. Geography should be constituted an elementary science subject. Instruction in science should be by special teachers as at Liverpool Board Schools; and higher elementary schools should supplement the Board schools, and be succeeded by laboratory practice in technical classes elsewhere. Inspection should be more frequent, higher grades better remunerated, practical work more encouraged, and proper apparatus provided.

In comparing drawing instruction in elementary schools at home and abroad, the inadequacy of our system becomes apparent. Drawing should be made compulsory; the importance of modelling, and of drawing to scale be insisted upon; and special grants should be made for specimens of applied art workmanship in the materials themselves. The value of local industrial art museums is insisted on, as a means of stimulating art progress, and the circulation of collections and manuals by the Science and Art Department is strongly approved.

Colleges should be of various grades; the value of the highest scientific training is not yet sufficiently recognised in this country, nor the importance of original research. Lastly the Commissioners give a special review of the work of the City and Guilds of London Institute for the Advancement of Technical Education—its Central Institution at South Kensington; its Technical College at Finsbury, both day and evening classes; its South London Technical Art School; and its technological classes throughout the country, and warmly commend its objects and organization.

The Commissioners then turn their attention to Ireland, and press the importance of promoting technical instruction in handicrafts and in home industries, instruction in the use of tools in primary schools, and compulsory attendance.

The subject of agricultural education is next discussed, which the Commissioners claim to be of national importance and interest in Great Britain, but to be a question of life and death to Ireland; they find that this is thoroughly felt both by the Government and by the people, and that there is progress in all directions.

Finally, the Commissioners sum up the results of their careful study of the whole subject of technical education at home and abroad, and of the evidence so freely given before them, by a tabulated list of recommendations with which this brief summary must close.

RECOMMENDATIONS.

Having carefully considered what is desirable and practicable in regard to the general and technical instruction of the various classes engaged in industrial pursuits in this

country, we humbly offer the following recommendations, which require the intervention of the Legislature or of public departments :—

I. As to public elementary schools :—

(*a*) That rudimentary drawing be incorporated with writing as a single elementary subject, and that instruction in elementary drawing be continued throughout the standards. That the inspectors of the Education Department, Whitehall, be responsible for the instruction in drawing. That drawing from casts and models be required as part of the work, and that modelling be encouraged by grant.

(*b*) That there be only two class subjects, instead of three, in the lower division of elementary schools, and that the object lessons for teaching elementary science shall include the subject of geography.

(*c*) That, after reasonable notice, a school shall not be deemed to be provided with proper "apparatus of elementary instruction" under Article 115 of the Code, unless it have a proper supply of casts and models for drawing.

(*d*) That proficiency in the use of tools for working in wood and iron be paid for as a "specific subject," arrangements being made for the work being done, so far as practicable, out of school hours. That special grants be made to schools in aid of collections of natural objects, casts, drawings, &c., suitable for school museums.

(*e*) That in rural schools instruction in the principles and facts of agriculture, after suitable introductory object lessons, shall be made obligatory in the upper standards.

(*f*) That the provision at present confined to Scotland, which prescribes that children under the age of fourteen shall not be allowed to work as full-timers in factories and workshops unless they have passed in the Fifth Standard, be extended to England and Wales.

II. As to classes under the Science and Art Department, and grants by the Department :—

(*a*) That school boards have power to establish, conduct, and contribute to the maintenance of classes for young persons and adults (being artisans) under the Science and Art Department. That in localities having no school board the local authority have analogous powers.

(*b*) That the Science and Art Department shall arrange that the instruction in those science subjects which admit of it shall be of a more practical character than it is at present, especially in the "honours" stage; that payment on results be increased in the advanced stages of all subjects, at least to the level of those now made for practical chemistry and metallurgy, and that greater encouragement be given to grouping.

(*c*) That the examinations in agriculture be made to have a more practical bearing.

(*d*) That metallurgy, if it be retained, be divided into groups, as (1) the precious metals, (2) those extracted from metalliferous mines, as copper, tin, lead, &c., (3) iron and steel. That mining be similarly divided into (1) coal and (2) metalliferous mining.

(*e*) That the inspection of science classes by the Science and Art Department, with a view to ascertain the efficiency of the instruction, and of the apparatus and laboratories, be made more effective, with the assistance, where necessary, of local sub-inspectors.

(*f*) That it shall not be a requirement of the Science and Art Department that payment of fees be demanded from artisans for instruction in the science and art classes.

(*g*) That in the awards for industrial design more attention be paid by the Department, than is the case at present, to the applicability of the design to the material in which it is to be executed, and that special grants be made for the actual execution of designs under proper safeguards.

(*h*) That the limits of the Building grants, under the Science and Art Department, to 500*l.* each for schools of Art and of Science should be abolished, and the conditions attached to them be revised.

(*i*) That, in addition to the loan of circulating collections and the grant of art reproductions at reduced cost, contributions be made to provincial industrial museums of original examples tending to advance the industries of the district in which such museums are situated.

III. Training Colleges for elementary teachers :—

(*a*) That the teaching of science and art in Training Colleges, and its inspection by the Science and Art Department, be made efficient, and that arrangements be made for giving to selected students in those Colleges greater facilities and inducements for the study of art and science in the National Art Training School and the Normal School of Science at South Kensington, the Royal College of Science for Ireland, and other Institutions of a similar class approved of by the Government.

IV. Secondary and technical instruction :—

(*a*) That steps be taken to accelerate the application of ancient endowments, under amended schemes, to secondary and technical instruction.

(*b*) That provision be made by the Charity Commissioners for the establishment, in suitable localities, of schools, or departments of schools, in which the study of natural science, drawing, mathematics, and modern languages, shall take the place of Latin and Greek.

(*c*) That local authorities be empowered, if they think fit, to establish, maintain, and contribute to the establishment and maintenance of secondary and technical (including agricultural) schools and colleges.

V. Public libraries and museums :—

(*a*) That ratepayers have power, by vote, to sanction the increase of the expenditure, under the Public Libraries Acts, beyond its present limit, and that the restriction of the Acts to localities having 5000 inhabitants and upwards be repealed.

(*b*) That museums of art and science and technological collections be opened to the public on Sundays.

VI. Special recommendations in regard to Ireland :—

(*a*) That steps be taken at the earliest possible moment for the gradual introduction of compulsory attendance at elementary schools in Ireland.

(*b*) That payments be made by the National Board, under proper regulations, on the results of the teaching of home industries to children, young persons, and adults ; as well as in aid of the salaries of industrial teachers.

(*c*) That systematic instruction be given to primary school teachers, qualifying them to teach the use of tools for working in wood and iron, in the primary schools.

(*d*) That steps be taken by the Commissioners of National Education in Ireland for the provision of books calculated to assist the teachers of primary schools in giving graduated lessons in rudimentary science.

(*e*) That grants-in-aid be sanctioned by the Treasury to approved agricultural schools, and to approved schools for instruction in local industries.

(*f*) That practical evening science classes for artisans form part of the instruction in the Royal College of Science of Ireland, in Dublin.

(*g*) That the Board of Intermediate Education take steps to ensure the provision of adequate means for the practical teaching of science in the schools under their direction.

In addition to the preceding recommendations which necessitate action on the part of the Legislature or of the public authorities, or of both, your Commissioners make the following recommendations, requiring no such action, by way of suggestions for the consideration of those in whose power it is to comply with them :—

I. That it be made a condition by employers of young persons, and by the trade organizations, in the case of industries for which an acquaintance with science or art is desirable, that such young persons requiring it, receive instruction therein either in schools attached to works or groups of works, or in such classes as may be available ; the employers and trade organizations, in the latter case, contributing to the maintenance of such classes.

II. That the managers and promoters of science and technical classes should (*a*) so arrange the emoluments of teachers as to encourage them to retain their students for the advanced stages of subjects in which they have passed the elementary stage, and (*b*) that they should endeavour to group the teaching of cognate science subjects, as recommended by the Royal Commission on the

Advancement of Science, and as provided for by the regulations of the Science and Art Department.

III. That scholarships be more liberally founded, especially for pupils of higher elementary schools, enabling them to proceed to higher technical schools and colleges.

IV. That the great national agricultural societies give aid to the establishment in counties of secondary schools or classes for teaching agriculture.

V. That those responsible for the management of primary schools in Ireland, in the districts where farming is defective, attach small example farms to such schools wherever it is possible; and that boards of guardians employ the plots of land attached to workhouses for the agricultural instruction of the children therein.

VI. That the subscriptions given by the liberality of the City of London and of the different Guilds, to the City and Guilds Institute, be made adequate to the fulfilment of the work which that Institute has undertaken, including the equipment and maintenance of its Central Institution.

CHAPTER III.

BUILDINGS FOR APPLIED SCIENCE AND ART INSTRUCTION.[1]

THE distinctive character of our times, according to Professor Huxley, lies in the constantly increasing part which is played by natural as contrasted with classical knowledge. The study of the natural sciences, hitherto relegated to the "modern side," is rapidly being included in the curriculum of every liberal education. The application of the principles of physical science to the development of mental activity, as well as to industrial enterprise, will in all probability be the distinguishing peculiarity of educational progress during the remainder of this century, that is to say, the study of things themselves, and not only their names, is destined to accompany where it does not supersede the study of language and general literature as a mental exercise. So great a revolution in the system of education points to a corresponding change in the design of the buildings required for its development, and thus gives the *raison d'être* for the subject of this chapter.

My chief claim to the honour of addressing professional men upon technical educational buildings is that I have visited the principal English and Foreign examples; in the former case accompanied by Professor Armstrong, and in the latter by both Professors Armstrong and Ayrton, who were instructed by the Guilds Institute to inspect the various *Polytechnica* of the German-speaking countries of Europe, prior to finally determining the fittings and apparatus which should be adopted at the Finsbury Technical College.

Some three or four years ago, when occupying the chair as Prime Warden of the Dyers Company, I advised that Company to give its support to the City and Guilds of London Institute for the Advancement of Technical Education, which led to my election to serve on the executive committee of that body; and in May, 1882, I delivered a lecture at the Society of Arts on "English and Foreign Technical Education," which forms the first chapter of this book. I have thereby cleared the way for this paper, treating on the kind of buildings which will in future be required. In the lecture referred to, I gave no illustrations of buildings, but confined myself to the general description of prevailing systems of

[1] This chapter was the subject of a paper read at the R.I.B.A. in 1883.

scientific education on the Continent, and contrasted them with our own, especially noting the extent to which strictly technical subjects are included in the curriculum of each.

Before proceeding with detailed descriptions, it will be desirable to give attention to certain general principles underlying or, rather, governing the planning of technical buildings. I am not aware that any attempt has been made to formulate them, at least in my own case I found it necessary to collect the *data* from original sources in order to frame a system. All technical education does not need special accommodation. The ordinary class-rooms attached to school buildings may be appropriated to certain kinds of technical instruction, provided they are efficiently lighted and ventilated; but there are many subjects which should be taught in specially designed buildings, for example, chemistry and physics, biology and physiology, botany and forestry, mechanics and engineering, anatomy, architecture and the fine arts generally, and others involving the provision of laboratories, lecture-rooms, work-rooms, drawing-rooms, modelling-rooms, &c., separately grouped in a certain order and contiguity, specially floored, lighted, heated, and ventilated, and arranged for particular furniture fittings and apparatus—not to speak of the specific trade schools for teaching weaving, dyeing, &c., &c.

In the older Continental polytechnic institutions, as at Zurich and Vienna, all these subjects are taught in different departments of one and the same building; and where the technical education attempted is limited in extent, the same arrangement suffices. Special technological research has, however, necessitated extensions in this direction; and at Zurich, Karlsruhe, and elsewhere, new and detached buildings have been added to the old foundations for technological and agricultural chemistry, botany, and forestry.

The great Universities of the Continent have also found it necessary to extend the laboratory accommodation, and to provide distinct buildings, which are erected in the neighbourhood. Thus, at Berlin, Professor Helmholtz's physical laboratory and its associated class-rooms and lecture-rooms are in one grand building, and Professor Dubois-Raymond's physiological laboratory is in an adjoining building,—worthy companions of the handsome structure erected for Professor Hofmann so long ago as 1865. At Leipsic is a street full of separate and distinct buildings for these subjects, supplementing the old University provisions, which, however, are very good. At Geneva, Professor Græbe has designed and superintended the general arrangement and fittings of the new chemical laboratory, also situated apart from the University proper. Professors Von Pebal and Toepler at Graz, Professor Landolt at Aachen and Berlin, Professor Bæyer at Munich, have each worked out with the respective architects the details of their new and remarkably well-fitted laboratories. At Strasburg the new University, which will be of a remarkably complete character, is being constructed in separate blocks. In addition to the main building for classical studies and general literature, distinct blocks are arranged for chemistry, physics, botany and forestry, mineralogy, &c., each block costing from thirty to forty thousand pounds, built in the classic style, faced with stone from the Hartz Mountains, and together covering several acres of ground. At Vienna the great University buildings in course of erection are similarly complete and extensive.

The study of the natural sciences abroad has become so popular that there is scarcely

any educational centre that cannot boast of some magnificent addition to its public buildings for scientific instruction within the last decade.

It is not surprising, therefore, that this country should feel the same impnlse, and that imposing structures should now be in demand in all our leading towns, some of which are already supplied by private benevolence or corporate funds, and in the case of Nottingham out of the municipal exchequer. The Science and Art Department at South Kensington is now too well known and appreciated to need any further reference. At University College, London, great additions have been made for the accommodation of applied science classes. Thus, besides the Slade School of Fine Art opened in 1871, new departments have been provided for since 1878, viz. zoology, comparative anatomy, physiology, technological chemistry, and an admirable engineering school.

To proceed to details. It is desirable in the first place to note the particular accommodation required for some of the leading special subjects, number and relative position of apartments, in short, the systematic general arrangement of the plan. In the arrangement of chemical laboratories, the central points of interest are the main laboratory and the lecture-rooms; in the former the working benches are required to be provided for each student with convenient access to a sufficient number of sinks and draught-closets, both on the benches themselves and around the walls. The junior students, or students of qualitative chemistry, sometimes occupy different parts of the same main laboratory with the senior students or students of quantitative chemistry; and sometimes, as at Owen's College and most of the Continental laboratories, they are provided with separate laboratories, in all cases overlooked from the demonstrator's raised operating-bench. In the generality of cases the students can all see each other and be supervised from the demonstrator's platform, but in some few cases, as at University College, London, they are so arranged that each student may be as far as possible separated from his neighbour, and from general supervision as a consequence. In all cases it is important that the re-agent store, the demonstrator's room, the special operating-room, and the balance-room should be in close proximity to, and of easy access from, the main laboratory or laboratories; their exact position varies, but on no account should any of the subordinate rooms form a passage to other rooms. Professor Hofmann's building in Berlin is defective in this respect, for the balance-room forms a passage between the two laboratories, and the delicate scales and weighing apparatus are subject to the vibration and disturbance of passers to and fro. Professor Helmholtz's building is spoilt by the glazed passages formed on either side of his lecture-room, and when his assistant was taking Dr. Armstrong and myself over the building, we were cautioned to go on tiptoe to avoid disturbing the professor, who was at that moment engaged in lecturing to a large class.

The lecture-room should always have a preparation-room adjoining the professor's end of the room, so that the preparation of examples and apparatus may be close at hand, and may be passed through the door or the large glazed draught-closet immediately behind him, about six feet wide, four feet six inches high, three feet from the floor, and three feet deep, the sashes provided being on each side of the closet. It is important that the lecture-room should also be in easy communication with the collections of models, apparatus, and examples required by the lecturer. The position of the lecture-room should be such that

no interruption of the lecturer may take place. The students' entrances should be at the upper end, farthest from the professor's table; his own end of the room should have doors of access to the corridor through the preparation-room and anteroom. There are numerous practical questions with which it is necessary to be familiar in order to avoid mistakes. Many thousands of pounds have been wastefully expended by architects, who have only sought to meet the wishes of an irresponsible committee, and have not been associated with the professor, whose appointment, in one case known to me, was not made till irretrievable mischief had been done. At the new Polytechnic in Dresden, the professor of physics was contemplating the removal of his department, owing to the vibration caused by the traffic in the street on that side of the building in which his department was placed. Delicate operations require the steadiest site. In the same way the special ventilation for chemical laboratories requires both common-sense and care, for many otherwise admirable systems have failed in consequence of the neglect of obvious requirements—till too late to amend them—chiefly arising from the want of a complete understanding between the architect and the ventilating engineer or the professor himself. Professor Græbe, of Geneva, stated that all his room ventilation at his chemical laboratory was effected through the draught-closets, no use being made of the general room-ventilating exit-openings leading to the base of the furnace-shaft; this latter, in fact, was a failure so far as the chemical laboratory was concerned, the greater pull being through the draught-closets, the air of which was sucked out by the fan fixed at the entry of the collecting channels, at the level of the roof, into the side of the great exhaust shaft, within which was the iron chimney-flue from the furnace. A similar result followed the otherwise excellent ventilating arrangements at Munich, Aachen, and elsewhere. In every case in which no special mechanical system was employed, the ventilation was practically *nil*, and in some cases, as at the comparatively old Polytechnics of Zurich and Vienna, was excessively bad.

Examples of Foreign Buildings to which attention is directed in this chapter.

(The English Buildings will be discussed in the fourth chapter.)

1. Professor Hofmann's chemical laboratories at the Universities of Bonn and Berlin.
2. The Munich University chemical laboratory, inspired by Professor Bæyers (see Plates 1 and 2).
3. The Berlin physiological laboratory after Professor Dubois-Raymonds (see Plate 3).
4. The chemical laboratory at Aachen, by Landolt (see Plate 4).
5. The Graz University chemical laboratory, after Professors Von Pebal and Toepler (see Plate 5).
6. The physical and chemical laboratories of the Royal Trade School, Chemnitz, by Professor Weinhold (see Plate 6).
7. The physical laboratory, Wurzburg, of Professor Kohlrausch (see Plate 7).
8. The Technical High School, Hanover (see Plate 8).
9. The Royal Technical High School, Stockholm, Sweden.
10. The Chalmers Industrial and Technological School Gothenburg, Sweden.

11. The Royal Technical High School, Charlottenburg, Berlin (see Plate 9).

12. The new chemical laboratories of the Polytechnic School, Zurich (see woodcuts).

13. The Central International Electrical Laboratory, Paris (see Plate 10).

14. The new University of Strasburg; its collegiate palace and surrounding scientific institutions.

15. The Conservatoire des Arts et Métiers, Paris (see woodcuts).

The above list is sufficiently representative of the older and the more recent science buildings of the Continent.

The Paris electrical laboratory is not yet realized it is true, and some are in process of completion or of extension. The new chemical laboratory at Zurich was opened only last October. My own tour in Germany was made in 1882. The itinerary was as follows: In January of that year I met Dr. Armstrong at Strasburg, to visit the grand University buildings then in progress, accompanied by the chemistry professor. Whence we proceeded to Mülhausen under the guidance of Dr. Witt, and eventually arrived at Geneva, where Professor Ayrton joined us on his return from Algiers. From Geneva we proceeded to Zurich, where Professors Lunge and Victor Meyer conducted us through the buildings; and on to Munich, where Professor Bæyer explained his admirable University laboratory, and Dr. Renk, Pettenkofer's Hygienic Institute, &c., &c. From Munich we went to Vienna, visiting the Polytechnic and other interesting educational buildings. Here we parted company for a time; Dr. Armstrong going to Graz and to Buda Pesth, while Professor Ayrton and I proceeded to Dresden and Chemnitz. Professor Ayrton then took Wurzburg on his way home, whilst I returned to Dresden to meet Dr. Armstrong and to study the new Polytechnic and other buildings. On leaving Dresden we went to Leipsic to see the old and new University buildings, and then on to Berlin, whence after a few days' stay we moved on to Aachen; this was the last place at which we stayed, returning home after a month's absence. In all these places we visited the University science buildings, and the Polytechnic, as well as other buildings of lower grade, &c., &c.

Before proceeding to the separate description of the foregoing examples, it may be desirable to call attention to the published opinions of Dr. Von Pebal, of the Chemical Institute at Graz, the plans for which building, in conjunction with Toepler, the physics professor, were definitely arranged by him; his remarks on the planning of chemical laboratories generally are exceedingly valuable; he tells us that no scientific institution requires the fulfilment of so many and such various conditions in its design and arrangement as a chemical laboratory, and the difficulties arising out of this, increase considerably with the number of students for whom practical instruction must be provided. The greater the number of individuals working simultaneously in a laboratory, the more necessary is it to isolate work of different kinds into separate rooms, in order to avoid mutual disturbance. Not only the size, but the number of rooms requisite, must be increased for a larger number of students; this, however, unavoidably entails additional distances and the consequent disadvantages, viz. loss of time, fatigue, and the difficulty of superintendence. After discussing various forms of plan, Dr. Von Pebal comes to the conclusion that an arrangement of the rooms round enclosed yards answers the best to the need of short distances and light rooms, and in order to avoid a great expanse or area of

building, the rooms must of necessity be in stories one above another. The arrangement and relative size of the rooms in the building depend essentially upon the principle and the dimension according to which the above-mentioned division of groups is designed. In most laboratories the beginners are in separate rooms from the advanced students, or if the principle of separation is based on the different kind of work, the qualitative is separated from quantitative analysis, and again both of these from the organic chemistry department. In the Chemical Institute of Pesth, close to a large laboratory for beginners, are several small rooms arranged as laboratories for from two to six advanced students. Each of these ways of separation has its own peculiar advantages; it is specially convenient for those who are engaged in independent scientific researches to have to share a room with a small number only, so that they can either make use of apparatus for any length of time, or leave it standing unused according as required. The erection of special qualitative and quantitative laboratories appeared to Dr. Von Pebal to be less worthy of imitation, because he considered it desirable for several reasons to give beginners practice in qualitative analysis simultaneously with simple quantitative methods. The incitement to work which a laboratory offers is proportionate to the varied character of the work which is carried on in it. Improved planning and arrangement, as well as good methods of ventilation and sufficient superintendence, have tended to lessen the difficulties of carrying out different kinds of researches at the same time and place. For this reason it is best to limit the number of these departments to two, each of which should be furnished with the most complete arrangements possible. Complete independence in the distribution of the working places is thus preserved, which renders it unnecessary to overcrowd one department and leave the other almost unused. The necessary working space can be made to answer to the requirements of the students, by placing half a working-table at the disposal of beginners, and a whole one at that of advanced students. For operations which require a large amount of room, and which cannot be performed at each working place, there must be certain spaces of which the necessary arrangements are at the disposal of each practical student.

A University laboratory, however, cannot be expected to take the place of a chemical manufactory, either as regards the necessary appliances for the preparation of large quantities of chemical substances or the learning of methods of manufacture, though modern progress in technical education is tending in that direction—witness the numerous specially technological institutions which have lately supplemented the older pure science colleges abroad—nevertheless, even in purely scientific researches, it not unfrequently happens that large quantities of substances have to be dealt with, and it is indispensable that young experimental chemists (especially pharmaceutical chemists) should be practised in the manufacture of preparations, and in putting together and handling the most ordinary apparatus and appliances; consequently there should be particular rooms for this purpose, in the arrangement of which special provision must be made for the requisite number of flues.

FOREIGN BUILDINGS.

1. The Chemical Laboratories of Bonn and Berlin.

One of the earliest laboratories is that of Bonn, beautifully situated in a park on the outskirts of the town: it was erected nearly a quarter of a century ago, at a cost of 20,000*l.* Almost simultaneously the Berlin laboratory was carried out at a cost of 32,000*l.* Plans of those buildings were published with Professor Hofmann's report of the same in 1866—which report formed the subject of an article in the Dictionary of the Architectural Publication Society.

At Bonn the arrangements are confined to one floor. At Berlin two floors, both having lofty basements. At Bonn the building has wide corridors surrounding and overlooking the great central quadrangle, in the middle of which is the large lecture-hall; while that of Berlin, being a town building and surrounded by buildings, has no such corridor, and is so arranged that the rooms are made passages, and even the balance-room is not sacred.

At both Bonn and Berlin, the basement gives accommodation for store-rooms for dry, solid and liquid re-agents, for large stores of glass and porcelain, for washing and for heating and ventilating arrangements. Laboratories for physiological chemistry, accommodation for the medico-legal investigations, and for animals undergoing chemico-physiological treatment, are also provided at Bonn, and at both, workshops, fuel and other stores are arranged.

At Bonn, the basement being more extensive, contains apartments which at Berlin are at the level of the ground, as furnaces for assaying, smelting, &c., with flues sixty feet in height to insure good natural draught; also specially arched niches, let into the walls and provided with enclosing iron doors, for the protection of the manipulator when experimenting with substances at high temperature in sealed tubes. At Bonn the ground-floor comprises spacious vestibules and corridors. The front and southern block is devoted to scientific collections, mineralogical and chemical museums, and a small lecture-theatre for special subjects; the east wing is appropriated to the assistants, and the west wing to the private laboratory, &c., of the director.

The great central hall for 250 students is 40 feet square, and 28 feet high (that at Berlin is 37 feet high, but it would have been wiser in the latter case to have reduced the height, or to have placed it in the basement, so that the light to the rooms around might have been less obstructed). In close proximity to the lecture-hall is the lecturer's assistants' or preparation-room, then rooms for apparatus, models, diagrams, &c., the professor's room, cabinet, &c. The two northern quadrangles on the right are surrounded with buildings devoted to practical instruction in chemical analysis and research; there are three laboratories each 54 feet by 22 feet, by 17 feet high, and fitted for twenty students each, or more in the junior classes. The first is for beginners, the second for advanced students, and the third for young chemists engaged in original experimental investigations. At the northern end of the laboratories are three operation-rooms, communicating with

each other, and by open covered colonnades. The remaining rooms are appropriated to volumetrical analysis; two balance-rooms for balances, air-pumps, barometers, and other delicate physical apparatus; two rooms for fusions and ignitions, a library, laboratory for gas analysis and photometric-room. Professor Thorpe, who was a student there, tells me that the distances were too great, and that the journey to the balance-rooms was postponed as long as possible, thereby confirming Professor von Pebal's injunction.

At Berlin the plan is more compact, but has many defects, which have been overcome in later laboratories, and it is now regarded as by no means an example to be imitated even by Berliners. There are two large laboratories at Berlin, 48 feet by 31 feet wide, for twenty-four students each, divided by a preparation-room, 32 feet by 20 feet, and a third laboratory, 47 feet by 24 feet for sixteen students engaged in original research, with a combustion-room attached. The open colonnades on the ground-floor carry galleries, that on the right being for the beginners' laboratory and the library; that on the left is in three portions, the two ends being for fusions and ignitions for the second and third laboratories respectively, the balances being in the centre between them, a defect already noticed and brought home to me by an accident which occurred as I was passing. The fire ran along upon the ground of the balance-room, and though speedily extinguished, proved the danger of making the subsidiary rooms passages between the main laboratories.

2. The Academy of Sciences, Munich. (See plates 1 and 2.)

I propose to treat rather fully of the new chemical laboratories of the Academy of Munich, because the building is one of the best examples of modern German work. In 1875, Professor Bæyer was commissioned to prepare the plans for a new chemical laboratory, in which he was associated with Professor Albert Grul, architect. In 1880, they published a pamphlet describing the same, and from this I have supplemented the information I obtained during my visit with Professors Armstrong and Ayrton. In dividing the plan, the following points have had to be considered. (1) The laboratory must accommodate from 150 to 200 workers; (2) It must be divided into two spacious parts, one for inorganic, and the other for organic chemistry, each to be under separate direction; (3) The director of each portion must have a private laboratory with the necessary extra rooms, the assistants to work in the large laboratories; (4) The main laboratories must be sufficiently spacious, smaller rooms for advanced students not to be provided, in order to promote the intercourse of the workers, corridors as far as possible to be avoided; (5) Living-rooms in connection with the building must be provided for the assistants and servants. The old laboratory and lecture-room of Liebig forming the central block, erected for him in 1852, were to be incorporated in the new building. The building is cellared throughout, and consists of a ground and first floor (see plates 1 and 2), the basement is used for store-rooms, work-rooms and furnace-rooms, &c.

The ground-floor is for the organic, and the first floor for the inorganic divisions. The central point of the separate large laboratories, of which there are two on each floor, is occupied by the big chimney, which is placed in the internal angle between the north

and west wings, which are at right angles with each other. At the ends of both wings, on both floors, are the two large work-rooms or laboratories; and from the connecting corridors between them, access is given to the subsidiary rooms. A hoist near the chimney communicates with the store-rooms. At the end of each wing of the separate laboratories are buildings. That on the south-west is the servants' dwelling-house; that on the north-east contains the two private laboratories. A better position, I think, for the professor's private work-rooms would have been to the north of the western wing, so as to be as central as possible between the students' work-rooms, but the exigencies of the site necessitated otherwise. A grand staircase was not provided, but two smaller ones are at either end of each wing. The first serves as a staircase for the servants' house as well as the students' western laboratories; the second connects the private laboratories and the general collections with the students' northern laboratory. The students' entrances are at or near these staircases, passing the vestibules, opening into which are cloak-rooms and retiring-rooms. The sole distance which the students have to go during work consists of the short walk to the special rooms in the corridor; if they wish to cross from the western to the northern laboratory, or to the basement or first floor, they can do so by using the staircase without making a thoroughfare of the laboratories. The staircases are of stone, and the basement and ground-floors are arched over. The large lecture-hall is entered from without by two students' staircases; behind the professor's table is the glazed chamber opening to corridor, through which apparatus is passed in from the preparation-room. A small theatre is situated on the other side of corridor. Beyond the preparation-room is the room for collections, over which is a similar room; the relative positions of these rooms, resulting from the adaptation of the old Liebig buildings, are not so good as at Aachen. From the lecture-room is a corridor connecting it with the detached dwelling-house of the professor. The main courtyard is entered from the Sophien-Strasse, between the servants' dwelling-house and the large lecture-room; it is enclosed on the west and north by the large laboratories, and is the thoroughfare to the two flights of entrance steps, and for carriages, carts, &c.

The Laboratories for the Organic Division, ground-floor, are fitted alike, but in Laboratory 2, which is for beginners, each table is intended for two students, whereas in Laboratory 1, which is for advanced students, a whole table is assigned to one, accommodating thirty-two students in the former and sixteen in the latter. The floors, for the sake of warmth, are made of wood, with an asphalte border round, three feet wide, on which stand the wooden sinks and digestoriums or draught-closets. In the middle of this border is an asphalte gutter-channel; this gutter is trapped at the two opposite ends, and communicates with the main drain. This channel carries away the wastes from sinks and draught-chambers, and also any floor-droppings, being covered only with perforated boards. This arrangement is said to work well in practice, and allows of carrying on large operations in the immediate neighbourhood of the work-tables; the central avenue being the general thoroughfare.

The Laboratories 3 *and* 4 *for the Inorganic Division, first floor*, are similar to the former. In each room there are ten double tables, each with three working-places on each side, so

that there is accommodation for sixty workers in each room, about three feet being given to each.

The Subsidiary Rooms to the Organic Division, ground-floor—A room for heating sealed tubes, called the cannon-room; glass-blowing-room; small combustion-room; preparation or specimen-room; washing-up-room, in which is the hoist, and it serves as a workroom for laboratory servants; large combustion-room; and balance-rooms; stink-chamber. Passing to the private laboratory block we come to the following subsidiary rooms:—library for the use of students; professors' consulting-room; professors' balance-room; air-pump and blow-pipe-room; specimen-room; washing-up and furnace-room; the private laboratory, which is at end of corridor. In addition to the work-tables there is a hearth for combustion. There are also draught-closets, the ventilation being effected by gas flames in the private laboratory, owing to its distance from the chimney-shaft.

The Subsidiary Rooms to the Inorganic Division, first floor,—filtration-room; blowpipe-room; smelting and air-bath-room; specimen-room; washing-up and servants'-room; stink-chamber; and balance-rooms; sulphuretted hydrogen-room. In the private laboratory are the following subsidiary rooms:—physical apparatus; professors' consulting-room; balance-room; and gas-rooms; washing-up-room with smelting-furnace, &c.; the second private laboratory.

The main building is heated by steam. The heating surfaces consist partly of chests, and partly of coils. The steam is generated in two large boilers, contained in the boiler-house placed in the courtyard. The servants' house is heated by stoves; the director's house by hot water; the lecture-rooms by coils with two small stoves in addition to the large lecture-room. In the laboratories are four stoves and two small coils.

The ventilation of the main laboratories is now effected by ascending flues from the draught-closets, sixteen in number. The laboratories are also connected with the general ventilating system, with descending extract flues as shown in section (see plate 2), but these are no longer used, as they were found to interfere with the ventilation of the draught-places. Experience has shown that the rooms are sufficiently ventilated, provided that all noisome operations are carried on in the draught places, fresh air being admitted very generally. The air as it enters the laboratory is led through short channels round the four stoves. The sixteen draught-closets are connected by means of glazed earthenware pipes with horizontal canals leading to a space in the roof through which runs the big chimney, and with which this space is put into direct connection. The draught up the chimney from the steam-boilers is sufficient in winter to work the arrangement; in summer it is necessary to urge it by means of a fan worked by a small steam-engine in the basement; the same arrangement serves to ventilate in addition the sulphuretted hydrogen-room and the stink-closets. The horizontal canals or channels, as well as the chamber with which they are connected, are made of bricks joined with asphalte and lined internally with the same material. The steam-boilers not only supply steam for heating, but also by a special service, for the drying-closets and the distilling apparatus. They also work a pump and the fan which sucks out the foul air from the basement channels with which the descending flues are connected.

3. THE PHYSIOLOGICAL INSTITUTE, BERLIN. (See plate 3.)

Through the kindness of Professor Lewis, who has lately made inquiries for me at Berlin, I am enabled to give plans of the new Physiological Institute at Berlin, which adjoins Professor Helmholtz's physical laboratory, and is in some respects explanatory of it, at least so far as the lecture-hall is concerned. It will serve as a good example of the manner in which these buildings are constructed, with the aid of government grants, by architects appointed by government, and usually themselves professors of architecture in one or other of the technical colleges. In this building the arrangement of the galleries of the hall is suitable enough, because they communicate with the hall alone; but in the physical laboratory adjoining, similar galleries are made the means of access to rooms beyond the hall, and consequently, though the gallery openings are glazed, traversing to and fro arrests the attention of both speaker and audience, which defect I noticed in my previous remarks.

The plan of this building, as a whole, is well conceived, and the various rooms are elaborately fitted up with every convenience.

On entering the *ground-floor* by the internal flight of vestibule steps, a wide corridor extends right and left. The large lecture-hall is immediately opposite the entrance. A comparatively narrow passage surrounds the lecture-hall on either side; next main corridor are two staircases of ample dimensions. Secondary circular staircases are at each end of main corridor, besides which are several small circular stairs communicating with the basement.

On the left of the entrance in front is the collection of instruments, beyond which are the assistants' rooms. On the right is the cloak-room, with staircase to porter's residence below. A mechanical workshop comes next, beyond which are the library and more assistants' apartments, communicating by stairs both up and down to other private rooms.

At the right end of main corridor is an exit to garden, on one side of which is the aquarium. At the left end of corridor are antechambers to the chemical private laboratory, and passing the battery-room we enter the private laboratory for physical physiology, beyond which are three rooms for physical physiology, the last opening into the preparation-room in the rear of the large lecture-hall. A circular stair gives access to a mezzanine gallery over antechamber and a room in roof over preparation-room. Behind the professor's private-room is another staircase, giving access to the dog and rabbit kennels in the *basement*, over which, on the right side of great-hall, are the vivisection-room, the microscopic gallery, and the anatomical collection.

The remainder of the basement is used as store-rooms for combustible materials and chemicals, &c.

The *first-floor* is devoted to chemical researches, spectrum analysis, balance and pump-room, and gas analysis room. There is also a microscopic gallery occupying half the right corridor, and the state testing-room opposite right staircase.

The *second-floor* has, besides the various assistants' rooms, a light and dark room for optical experiments and for photographic work.

The lecture-hall gives a fair sample of the decorative character of these public buildings devoted to science, and the lavish expenditure which characterizes them.

The paternal government of Continental nations is seen to perfection in these vast enterprises so fraught with incalculable benefit to the people for whom they are provided. Proud as we are of our independent efforts, it might not be out of place to consider whether our own Government might not take a livelier interest in the development of scientific and technical education, and contribute something towards the enfranchisement of the people from the ignorance which is inseparable from the want of such advantages.

4. The Chemical Laboratory, Aachen. (See plate 4.)

The buildings at Munich, Aachen, Graz, and Leipsic are examples of modern German chemical laboratories as late as 1879 and 1880; and in each is taught the same sound lesson, only in different ways, suited to the peculiarities of the circumstances and the character of its director. Professor Landolt's building at Aachen is replete with every scientific convenience, and is of all others an example of successful heating and ventilation; the fresh warm air is forced in by a fan, and the foul air is sucked out by two fans, without any conflict in the action—the *push* and *pull* principle pure and simple; and the whole is under the control of the engineer, who has an electrical tell-tale dial arrangement, by which he can know the temperature of every important room in the building, and appliances to enable him to "temper the wind" when necessary. The arrangement of the plan is good, if we except the front corridors, which are vaulted and sumptuously painted, and as a matter of fact are more ornamental than useful.

The subsidiary rooms to the lecture-hall are admirably grouped around it. The fine balance-room lies between this group and that of the quantitative laboratory, with which it directly communicates; organic chemistry, special operations, gas analysis, &c., are in the right wing, and in the left are the qualitative rooms and the small lecture-room. The laboratories are single-story buildings in this case, and are lighted from the roof as well as the sides. It is a costly erection, faced with stone, and the theatrical effect of the interior of the lecture-hall is extremely good.

The building may be said to consist of two separate departments, one for organic chemistry, and one for inorganic chemistry; that for inorganic chemistry comprising two distinct laboratories, the one devoted to quantitative, and the other to qualitative analysis. These laboratories are very completely fitted, each student's place being furnished not only with gas and water, but with an exhaust filter apparatus, with a vacuum, with steam, and with an air blast.

5. The Imperial University of Graz. (See plate 5.)

The Chemical Institute at this University, begun in 1874, was not completed till 1879. Professor Von Pebal published an account of it in 1880, from which my information is derived. It is economically built of brick, with plaster dressings internally and externally. The floors of the rooms are either of asphalte, cement or deal as required. Great care has been taken in all that relates to the efficient working of the institution, as the construction

of working-tables, draught-niches and places—experimental trials being first made—and the total cost was upwards of 50,000*l.* The first air was forced in by fans, through five distinct steam-heated heating-chambers, and the air is changed three times in an hour. The *push* principle pure and simple is adopted here without conflicting draughts. The entrance vestibule and great corridor is a decided improvement on Aachen. The residences occupy the right wing; the lecture-hall the central block, and the laboratories the left wing. The subsidiary rooms in connection with the lecture-hall consist of the professor's retiring-room and private corridor to front hall; the preparation-room, and two rooms for collections. The students have a fine anteroom for hats and coats, giving access to the upper part of the lecture-hall. The subsidiary rooms in connection with the laboratory are arranged at both ends of it, but the opposite doors opening into the spaces between the benches and the draught-closets, lead to making a thoroughfare of what at Munich is so much more usefully added to the working space; nor do I think that the arrangement of this room, with a working-bench in each window, besides the central row of double benches, is an improvement on the Munich plan of putting the draught-closets in the windows, and the sinks against the piers between, although the accommodation may be relatively greater.

6. The Royal Trade School, Chemnitz. (See plate 6.)

The town of Chemnitz in Saxony, has recently been brought into prominent notice through the publication of M. Felkin's pamphlet upon the educational advantages of a technical character which it possesses. It has no University, it has not even a Polytechnic so called, but it is full of High schools for general and special education, and is especially strong in Trade schools. I select for illustration the Royal Trade School, comprising the *Gewerbschule*, the *Werkmeisterschule*, and the *Baugewerkenschule* for artisans, which I visited with Professor Ayrton. The grand staircase is opposite the main entrance; the chief corridor runs right and left, and returns at right angles in both wings, but except in the basement the wing-corridors are utilised as rooms. Left of the staircase on the ground-floor is the chemical store-room, and the general chemical collection is next to it. The chemical laboratories for students in the first course of the Trade school occupy the whole of the left wing. The lecture-room adjoins, and the teachers' rooms are on either side of the main entrance; the room on the right is at disposal. The right wing is devoted to mineralogy; first the teacher's laboratory, next the mineralogical collection, then the lecture-room, a room for delicate work, and a waiting-room, bring us round to the main staircase again, on either side of which are conveniences. Descending to the basement, and taking the same route, we come to the gas-metre-room and two store-rooms, and a galvanic battery-room. In the left wing is accommodation for furnace operations, for steam operations, and a mechanical workshop. Then come two rooms for fire operations, and under the main entrance a photometric-room, the gas analysis-room, and the large fuel store-room, which is now used for physical experiments. The right wing is devoted to house stores: the small room at the back, which is the pendulum-room, extends the whole height of the building, with a small gallery at each floor, where experiments in connection

therewith are made. A similar pendulum-room or tower, is provided in the central well of a circular staircase at the physics laboratory of the new University of Strasburg.

Ascending to the first floor we enter the technical chemical collection. The left wing is devoted to the *Werkmeister* or foremen's school, first a teachers' laboratory, next the students' laboratory or general experiment room, and last, a spectrum analysis room. Adjoining the left wing in front is the lecture-room for technical chemistry, and there are three work-rooms for assistants and lecturers on physics. The remaining rooms are for the department of physics, first the lecture-room for physics for students of the foremen's schools, with a preparation-room between it and the lecture-room for physics for students of the *Gewerbschule*. It will be observed here that the lecturer's table in each lecture-room, has a portion which is made movable, so that apparatus arranged thereon may be moved along the tramway to and fro, for the service of both classes of students. Professor Weinhold gives details of this table in his book. The other three rooms are occupied by physics, apparatus-collections, without which no technical physics-teaching can be effective. The small room next the large lecture-room is used as a dark-room for experiments on light, and being situated at the end of the long corridor, a ray of light may be thrown through the door the whole length thereof. The arrangements for darkening the lecture-rooms at the professor's will, the spectrometer, the vacuum process, and a variety of special arrangements for gas, water, quicksilver-baths, steam drying cylinders, electrical apparatus &c., are far too numerous to mention. Professor Weinhold's perfect command of the English language enables him to give full information to Englishmen, and to no better place than Chemnitz could any student go to perfect himself in technical or applied science school requirements.

On the second floor of this building, starting from the left of the main staircase, we come to a store-room, an apparatus-room, a work-room for the chemistry assistant, and a balance-room. The chemical laboratory of the students of the first and second course of the *Gewerbschule* occupies one side of the left wing, adjoining which is a room for elementary analysis, and sulphuretted-hydrogen. The next front room is for general experiments by students as above, with a waiting-room adjoining; then come the balance and microscope-rooms, then the technical chemistry teacher's work-room. The rest of this floor, except the physics collection on the right of main staircase, is devoted to the teacher's apartments. This is an interesting example of the sort of building required at every industrial centre for the development of elementary technical science and art among foremen and practical men generally.

7. The Physical Institute, Wurzburg. (See plate 7.)

Professor Kohlrausch's Physical Institute is an interesting building, specially devoted to one purpose; and Professor Ayrton, who recently visited it, highly commended all its arrangements. The entrance to the principal floor is at the west end, the assistant's apartments are on the left of the entrance, and on the right is the passage to the lecture-theatre, in communication with which are the preparation-room and two collections of apparatus, models, &c., between which is the staircase. The main corridor extends from west to east,

from which seven laboratories are entered, and a third collection-room towards the north. Descending the staircase, we reach a large hall, with exit to yard, next which is the engine-room, with a gas-engine and electro-dynamo ; on the north side, communicating with each other, are two laboratories fitted with stone tables, sinks, and evaporating-closets, next to which is a store-room ; there is also a scullery with circular stairs to the floor over ; a large laboratory is at the east end, and next a chemical-laboratory ; the heating chamber and coal-cellar adjoin, and a workshop with forge and sink. The building is heated with hot air by flues, and the foul air is withdrawn by the furnace of the heating apparatus by descending channels. The remaining rooms are for servants' residence and domestic offices.

8. The Technical High School, Hanover. (See plate 8.)

This important, complete, and well-appointed technical school, consists of a cellar story, a ground story, the principal or first story, the second and third stories. It is designed in the palatial manner which always distinguishes German educational buildings. There are five open courts enclosed in the ground plan of the building, which measures 500 feet long by 250 feet in depth. Flights of external and internal steps give access to the great corridor, 120 feet long by 20 feet wide, forming one side of the central quadrangle, which is entirely surrounded by wide corridors, and intersected in the middle by the two grand staircases, connected by the *foyer* on this floor. On the right of the chief entrance we find a passage to the chemistry and physics departments, a lecture-room and a preparation-room for analytical chemisty, beyond which are two chemical laboratories separated by a special operation-room. Passing up the corridor of the extreme right wing at right angles to the front we have the room for gas analysis, the library and balance-room, the instrument-room and the staircase to the next story of this wing, which is entirely devoted to chemistry. The professor's private rooms and laboratory occupy the rooms over those last described ; on the other side of the staircase to the left is the chemical manufacturer's collection. The lecture-room for technical chemistry, its preparation-room, and its chemical collection follow, and beyond is an assistants' laboratory. On the right side are the collections of models or examples, and more assistants' rooms ; opposite the end of the corridor is the entrance to the gallery of the examination-hall, and to the left is the large lecture-room for chemistry with its satellite, the preparation-room. Descending the staircase to the floor below, we enter the physics department ; on the left of the corridor is the small lecture-room for physics, with its preparation-rooms and physics collection-rooms. The whole of the rooms on the right side of the corridor are devoted to the physics work-rooms or class-rooms. The examination-hall is at the end of the corridor and to the left is the large theatre for physics, with its preparation-room and professor's room. Returning to the main corridor and along the corridor of the right intermediate wing, we pass the botanical and zoological collections, the housekeeper's room, and the engineering lecture-room ; at the end of this corridor to the right is the refreshment-room ; turning to the left, the whole of the remaining rooms in this front are devoted to the engineering classes, with a collection of drawings adjoining the professor's room in the centre, drawing-class-rooms on either side, and a lecture-room for mathematics and mechanics,

in all 330 feet in length. Returning to the left intermediate wing, and passing the engineer's store-room, the teacher's private room and sitting-room and cloak-room, we come to the passage to the library, the reading-room, and the librarian's room. The remaining portion of this floor is given to the administrative offices and the director's residence, the domestic offices being on the floor below. Ascending the rear main staircase, we arrive in the midst of a series of drawing-rooms and lecture-rooms for architecture and building, divided into four classes of students; the professor's room and the specimen collection are in the centre, and the lecture-rooms at each end. The left wing is occupied by a collection of models of building construction, a lecture-room for technology, a professor's room, and large rooms for technological collections. Returning to the left intermediate wing, we pass another lecture-room for second and third classes in building and architecture, and we come to the laboratory for geology and mineralogy, the mineralogical collections, divided into two halls by the professor's room in the tower over the main entrance. The right intermediate wing contains two professor's rooms, a practical geometry class-room, a collection of mathematical instruments, and a lecture-room for practical geometry and mechanics. Proceeding up the rear or north grand staircase we arrive in the midst of the mechanics department. The drawing class-rooms occupy the whole of the northern front, except the lecture-room for the mechanics students and teachers; a professor's room is at each end of the corridor. The western side of the quadrangle is the large room for the first building and geometrical drawing-classes. The eastern side is entirely devoted to the mechanics collection. The southern side, with windows looking north, is the freehand-drawing school, and the collections are on the southern side; three professor's-rooms occupy the south-west angle. The basement is chiefly devoted to residences for the various officers, as the professors of chemistry and physics and their assistants, the workmaster and machinists, the housekeeper, the secretary, &c., &c. Under the library and reading-room is a vast room for technical experiments, and on the western side of the northern front, under the engineer's drawing-school, is a second freehand-drawing class-room. The important part which drawing takes in this institution is one of its most remarkable provisions. The remainder of the basement contains the heating apparatus and ventilating arrangements, and a series of cellars for the chemistry and physics department is in the east wing.

9. The Royal Technical High School, Stockholm.

The earliest provision for technical education in Sweden was in 1809, when lectures were given to artisans privately in chemistry and physics. In 1813 the Mechanical School was founded at Stockholm; in 1822 the School of Mines; in 1825 the Royal Technological Institute; by 1860 25,000*l.* had been spent in new buildings, and 2500*l.* a year granted by the State. In 1866 the School of Mines was incorporated with the Royal Technological Institute, and the whole denominated the Royal Technical High School; 6000*l.* more capital was granted, and 1000*l.* a year more income. In 1876 the department of architecture was instituted, in addition to practical mechanics, mining, science, and civil engineering. The High School possesses rich collections of models, instruments, &c., geological and mineralogical specimens; and a library of 18,000 volumes, besides 95,000

English Patent Office reports.* There are about 300 students, and the expenditure is some 10,000*l.* a year.

10. The Chalmers Industrial School, Gothenburg.

Founded in 1829 with half the fortune of William Chalmers, of English parents, and a merchant of Gothenburg. This industrial school is now a thriving institution, with 162 students, and an income of 2000*l.* a year. Spinning, weaving, navigation, hydraulics, chemistry, and mechanics are taught.

11. The Royal Technical High School, Berlin, near Charlottenburg.
(See plate 9.)

This magnificent building, erected and equipped at a cost of over 400,000*l.*, is situated in the midst of charming grounds, on the south side of the Berliner-Strasse, to which it displays a recessed frontage of about 670 feet. The garden frontage of the main building over 600 feet long and 160 feet deep, has five internal open courts, each about 70 feet square. The eastern and western wings are 270 feet deep. The edifice is four stories high.

Plate 9 gives the ground and first-floor plans, which are enough to show the general arrangement of the rooms, the description of which is given on the plans themselves. In line with this building and facing the Berliner-Strasse is the chemical laboratory of Libermann, and the photo-chemical laboratory of Professor Vogel, occupying a site of some 200 feet square, and enclosing two internal open courts about 100 feet long by 45 feet wide.

Obviously, foreign Governments are alive to the movement going forward in this country in favour of technical education, and they seem determined not to be behindhand in the race for supremacy in applied science instruction; but it is noticeable that the whole of this huge building is devoted to lecture-rooms, museums, and private apartments; there are no laboratories, except the chemical and photo-chemical, which occupy a separate building, and an "electro-technical" consisting of only a couple of rooms in the basement of the main building. There is no engineering laboratory. In these respects we are distinctly ahead of the Germans.

12. The new Chemical Laboratories of the Zurich Polytechnic School.

Since my own visit to Zurich in January, 1882, a most remarkable work has been conceived and executed, and in October, 1886, was opened the largest and most perfect institute for teaching pure and applied chemistry as yet erected. In 1883 the Federal Parliament voted the sum of 70,000*l.* for the new building.

The plans were prepared and designed by Messrs. Bluntschli and Lasins, professors of architecture in the Zurich Polytechnic School, in accordance with the programme submitted by Professors Victor Meyer and Lunge; but the internal fittings have been devised by

Professor Lunge alone, with the help of the architects.* Accommodation was to be provided for 200 students, but in reality there is accommodation for many more.

The ground floor of the west wing, that is about one-sixth of the building, is occupied by the Federal Assay Laboratory for Agriculture, and the Federal Institute for the control of Seeds. The remainder of the building is devoted to the chemical laboratories of the Polytechnic School. The northern half is taken up by the "Analytical Laboratory," with the exception of four rooms on the ground floor, which contains the laboratory for assaying gold and silver, under the care of the professor of technical chemistry. The latter has also charge of the whole of the southern half of the building, containing rooms for pharmaceutical chemistry, and for photography, along with those for technical chemistry proper.

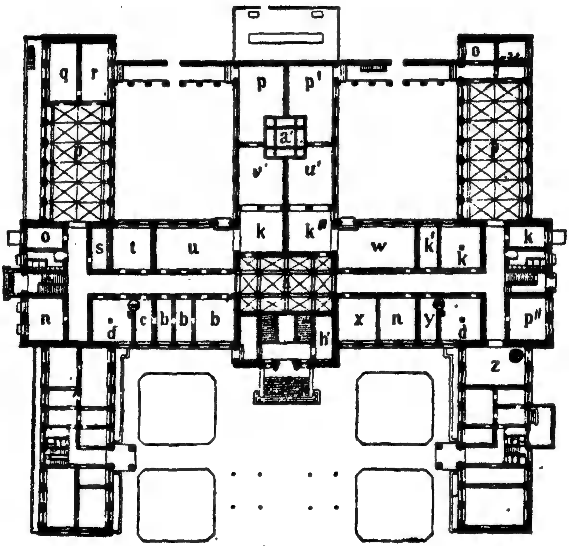


FIG. 1.

The following description and the illustrative plans appeared in No. 18 of *Industries* on the 29th of October, 1886:—

"Referring to the plans published herewith, Fig. 1 shows the ground floor, Fig. 2 the first floor, and Fig. 3 the second floor, above which there is a technological museum, forming the top of the building. On entering by the principal doors, a visitor finds himself in a large hall marked *a* (Fig 2). Immediately in front is a small lecture-theatre *c*, provided with seats for fifty students, and with all appliances for experimental work, including a preparation-room *b*. This theatre is used for the classes on pharmacy, and those given by the "Privat-docenten." *d* is a private room for the professor of

pharmacy; *e'* the pharmaceutical laboratory for twenty students; and *d'* a pharmaceutical museum, used also for microscopical practice in this department. A lobby *v* communicates between the south side of entrance and the chief professor's consulting-room, marked *u*; *w* is the assistant-professor's room, *t* the professor's private laboratory, *s* a balance-room, and *r* the principal store-room, communicating by means of a staircase with a

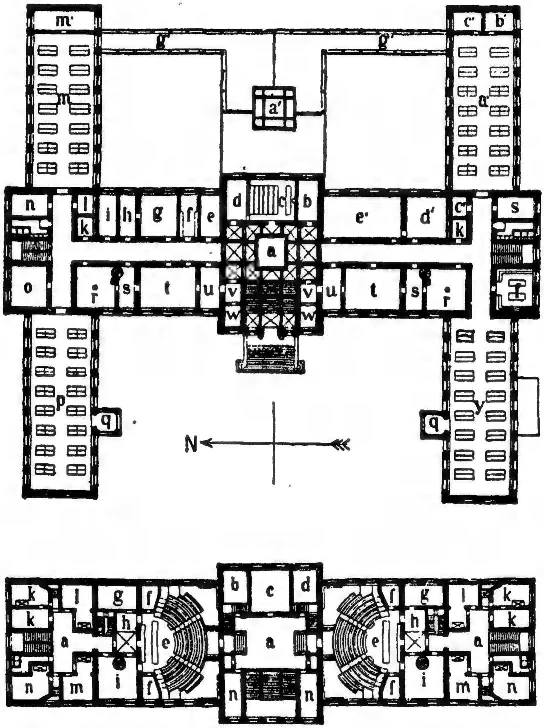


Fig. 3.

similar room *d·* on the ground floor (Fig 1). This arrangement is repeated in the block on the north side of the main entrance, which is devoted to analytical chemistry, *e* and *i* being special store-rooms, *f* the library, *g* a chemico-physical laboratory, *h* the organic balance-room, and *l* and *k* two dark rooms for optical purposes. Still keeping on this side, *o* is the analytical balance-room, *n* a special room for high temperature operations under pressure, while *m* and *p* are the large working-rooms, with fourteen and sixteen

double benches respectively; *m'* is a combustion-room, *q* a verandah, and *g'* a gallery leading to a covered space for outdoor work. The same arrangement as in the analytical laboratory is carried out in *y* and *a'*, with benches for about 100 students; *b'* is an optical-room, and *c'* a combustion-room. On the ground floor (Fig. 1), *z* is a room for practising photography, connected with a set of rooms underground by means of a spiral staircase; *p''* is a laboratory for night work; *k* contains steam-apparatus for distilling ether, benzine, or other very inflammable liquids, no gas or fire being allowed in this room; *p* is a large operating-room with stone benches along the sides and centre; *o* is a gas analysis-room, and that next to it forms a special laboratory for advanced students; *d* is a store-room, *y* a private laboratory, *u* and *x* rooms for experiments in dyeing and tissue-printing; *h'* a porter's lodge; *k'* a room for electro-chemistry, containing a large dynamo, driven by shafting from the room *w*, in which are a number of grinding and other machines. In *k''* is a battery of twelve steam evaporating pans, and a large steam-oven; *u'* contains a large number of crucible furnaces, which send their smoke and gases into the main chimney-shaft *a'*. Below *p* and *p'* are the steam-boilers. Turning now to the analytical side, *b b b c* are gold and silver assay rooms, *s* the magazine, *t* a room kept apart from the others for legal analyses, *u* a room containing steam baths, *o* a gas analysis-room, and *n* a room for special night work; *p* is a large operating-room, whilst *q* and *r* are at present not utilized for any special purpose. From *r* an arched gallery leads to *p* and *v'*, the pyrotechnical rooms, and back through *k* into the hall *a*. On the second story (Fig. 3), the large lecture-theatres *e e* are entered, either from the vestibule *a* (which is the students' entrance), or from the preparation-rooms *h h*. The latter communicate with the rooms *g g*, containing a collection of chemicals, and the rooms *i i* for apparatus. The other rooms at each end are demonstrators' living-rooms. The last part of this laboratory consists of analytical collection-rooms *b c d* accessible from the theatre *c*, and from the hall *a*.

Special notice should be taken of the details and fittings. Each beginner's place on the working benches, in the large rooms as well as in the smaller laboratories, is provided with two gas taps, one water tap, and one vacuum tap. Over and above this each double bench has at either side a water-basin, with a special water-tap and waste-pipe. The benches are provided with a number of closets and drawers of different kinds, and a special flat, with a lead-lined receptacle below for solid refuse. In every window niche there is a draught place, with a slate bench, gas, water, vacuum, and waste-pipe. These evaporating niches are over three feet wide, and therefore large enough to take good-sized apparatus; they can be divided into two compartments by means of a central sliding window. The draught is produced, first, by double chimneys passing through every one of the window piers; secondly, by pressure in the rooms; thirdly, in case of need, by a special gas jet lighted in the exit hole. There are two end holes on each side of the niche, one close to the top and another near the bottom of the niche, the second hole being intended for introducing any pipes conveying noxious gases.

The common places in the operation-rooms on the ground floor *p p* are fitted up with slate benches, water, gas, vacuum, draught hoods, and so forth, and in addition with

steam taps in every window niche. Here operations on a somewhat larger scale are to be carried out, such as need the use of charcoal furnaces. The vacuum and compression are produced by continuously working pumps, exhausting or compressing the air in large regulating vessels, from which a network of pipes and taps spreads through the whole building. Special attention has been paid to the question of heating and ventilation, and it is believed that no more perfect system for the special object in view has ever been carried out. We have already mentioned the steam-boilers; these are fifty-five horse-power, and furnish the steam necessary for heating the rooms, for supplying the numerous steam-heated laboratory apparatus, and for a twelve-horse-power engine, whose principal work is to set a large blast fan in motion. This fan blast aspirates air from without, which can be filtered and artificially cooled by a spray of water as may be required, and forces it through a complicated system of flues, communicating with every single room of the building through one or more louvred openings. In certain parts of these flues there are systems of pipes, through which the exhaust steam of the engine, and, in case of need, steam direct from the boilers can be passed, in order to heat the ventilation air up to the intended temperature. This heating of the air suffices for autumn and spring; whilst for the proper winter heating, special steam heating-apparatus, supplied direct from the boilers, are provided in each room, and are worked on the circulation principle. The air forced into the rooms enters at a height of about seven feet, and finds its way out, partly by special louvred openings near the ceiling, and in all the rooms provided with draught places (evaporating niches) partly through the latter. It must be remembered that all the window piers are perforated from top to bottom with upright shafts, which end over the flat roof in hooded terra-cotta pipes. Thus the fresh air introduced in one or more places (according to the size of the room), and producing a slight over-pressure within the rooms, must make its way out either in a great many places all over the room, or, if desired, exclusively through the draught places, so that the noxious gases there generated cannot by any possibility flow back into the room. The upper parts of all the windows are hung on horizontal swivels, and can be opened from below in a moment by pulling a cord, if at any time an unusually large amount of noxious gas should be evolved outside the draught places. There is also in every one of the larger rooms a large sink, covered with a draught hood, for emptying liquids which would cause a smell in the rooms. The arrangements are altogether worked out so completely that no special "stink-room" is required, since *all* rooms are adapted for carrying on all sorts of work without nuisance."

13. THE PROPOSED CENTRAL ELECTRICAL LABORATORY, PARIS. (See plate 10.)

In the March number of the *Revue Internationale de l'Electricité et de ses Applications*, 1886, an account is given of a proposal to establish a Central Electrical Laboratory of an international character, at a cost of some 13,000*l.* or 14,000*l.* The exact use that will be made of the building remains to be seen, but as there is at the present time a proposal before the Society of Telegraph Engineers and Electricians of London of a cognate character, it may be useful to give illustrations of the French laboratory. The idea of the English engineers and electricians is to see whether it is not possible to create a laboratory

in which electrical instruments can be standardised, as thermometers are at Kew at the present time, and it is probable that this will be one of the uses to which the proposed French laboratory will be put. Moreover, as there is included in the building an amphitheatre to hold some four or five hundred people, it is clear that it is contemplated to give lectures there, so that some instruction, at any rate, will take place in the buildings. It is possible that eventually similar work may be done there as that Professor Ayrton is doing at the Central Institution of the City and Guilds of London Institute, with the addition of standardising electrical instruments for a small fee. However this may be, it foreshadows a great movement towards the development of electrical science and practice in foreign centres.

Of the woodcuts given in illustration of this building, I have selected the ground and basement plans. There is a first-floor plan over the central block, and a roomy attic over that, at present unappropriated; but on the first floor are the physical and chemical laboratories in the rear of the centre, with conference meeting-rooms on either side. And the front portion is occupied by the resident director and secretary's apartments.

Ground Floor.—A handsome flight of steps gives access to the grand entrance-hall and vestibule. The principal staircase is on the left, and the secretary's office on the right, beyond which are two offices of administration. On the other side of the staircase are the lavatory and cloak-room.

Immediately opposite the main entrance is the laboratory for electrical experiments, about 120 yards superficial—the floor of which is sustained on four columns—on one side is the grand hall of the commission, and on the other their study or reading-room, beyond which is the library and museum; in a corresponding position at the other end of the building is the lecture-theatre for four or five hundred persons. The central block is four stories in height including the basement, but the wings are two stories, to allow for their higher basements and lofty domical roofs. The height to the springing of the domes is about twenty feet, and the total height forty feet, while the basement under is sixteen feet high. The floors of the amphitheatre and library are each sustained by a double row of columns.

Basement.—Descending to the basement, we find the space under the electrical laboratory is occupied as a large general receiving and distributing-room. There are two external staircases down to it. Two lifts which rise to the topmost story and serve each floor of the central block, besides a service staircase to all floors.

On the left side of this room is a workshop, and on the right a store-room. The right wing is occupied by the storage of electricity, batteries, &c., and the left by the steam-engine and dynamos, and other electrical machinery.

The remainder of the basement is devoted to the administration generally.

14. THE NEW UNIVERSITY OF STRASBURG.

On Monday, October 27th, 1884, this wonderful series of high educational buildings was opened with due formalities. Two years previously, in company with Dr. Armstrong, I wandered through the buildings then in course of construction, Professor Fittig being

our guide to the chemical and physical laboratories then approaching completion. These buildings form an entire quarter of the city, and constitute a magnificent series of palaces for the prosecution of science. No city in Europe (to quote the article in *Nature* of April 16th, 1885, slightly abbreviated from the original paper published in *La Nature*, by M. Chas. Grad), not even excepting the great capitals, can show such a rich provision for higher education, or one in which the various parts are so admirably combined. Every branch of study has its own proper and distinct location allotted to it, with laboratories, museums, library, and special appliances. In 1885 the University of Strasburg counted seventy-three ordinary, and nineteen extra-ordinary professors, and nearly 900 matriculated students. Since the annexation of Alsace-Lorraine, the sum spent on this University has been upwards of 640,000*l.*, without reckoning the value of the establishments of the Antient Académie, or the cost of the library of 560,000 volumes, which was 71,400*l.* There is also an endowment of 43,000*l.* for the maintenance of the University, and one of 6000*l.* for that of the library, both charged to the Imperial budget to meet the current necessities, in addition to the income derived from the older special endowments.

Professor Warth, of Carlsruhe, was the architect and director of the works from 1874 to 1884. The main building is called the Collegiate Palace, and is a sumptuous structure. The special institutes of chemistry, physics, botany, pharmacy, and astronomy, are grouped around the Collegiate Palace, and merit a particular description, as well as the hospitals of surgery, obstetrics, and psychiatry, and the institutes of anatomy, physiological chemistry, and of physiology belonging to the science of medicine, which are grouped around the Civil Hospital. Each of these institutes is independent of and situated in a separate block of buildings from the others, and provided with everything appropriate to its specific purpose.

To complete the organization of the University establishments there remain to be erected an institute of geology, and of zoology, and of meteorology.

Towards the total sum of 640,000*l.* spent up to 1885, the German Empire has contributed 190,000*l.*; of this sum 115,000*l.* were spent on the Collegiate Palace. The institute of chemistry alone cost 35,000*l.*; the institute of physics, 29,150*l.*; the institute of botany with its garden, 26,200*l.*; the astronomical observatory, 25,000*l.*; the institute of anatomy, 41,740*l.*; the surgical clinical hospital, 26,500*l.*; the institute of physiological chemistry, 16,000*l.*; the institute of physiology, 13,500*l.*

Henceforth, in the opinion of the writer of the paper in *La Nature*, the institutes annexed to the University of Strasburg will serve as models for the installation of similar buildings. They are not only most complete, but are already sought by students.

Thus the institute of chemistry, under the direction of Professor Fittig, is designed to receive 100 students in its two divisions of organic and inorganic chemistry; and there is not a single vacant place.

Surely it is time for our people to bestir themselves, for the competition for excellence is pressing hard upon us, and the advantages to be obtained by culture are greatly in favour of those nations whose Governments not only recognise, but assist the development of the national intellect.

15. The Conservatoire des Arts et Métiers, Paris.

The illustrations given of the Conservatoire des Arts et Métiers are from woodcuts given in No. 31 of *Industries*. The editor very justly observes in his description, which extends over three numbers of the Journal, that this institution is an example of what can be done by judicious Government assistance to advance scientific and technical knowledge; that whatever difference of opinion there may be about Government interference in purely teaching institutions, there is practically none about the advisability of either the central or local Government establishing and maintaining libraries and museums for the benefit of the people. We have our British and South Kensington and other museums, but there can be no doubt that the Conservatoire des Arts et Métiers, Paris, is *facile princeps* of the museums of practical mechanics in the world, and may be regarded as one of the most important institutions of France, on account of the eminently practical services it renders by its collections, its public courses of lectures, and its library. As the new buildings of the École Centrale are quite close to those of the Conservatoire, the students of that institution will be able to take advantage of its vast resources.

The Conservatoire des Arts et Métiers owes its origin to Vaucanson, who in 1775 formed a collection of machines, models, and instruments intended for the instruction of the working-classes. Vaucanson died in 1783, and bequeathed his collection to the Government, and from that date to the revolution of 1789 it made slow but steady progress, when it was reorganized by special decree in 1794.

After a few temporary lodgments the collection was established in the ancient priory of Saint Martin des Champs, in 1789, and there it has remained till the present day. The ancient buildings, however, now only form a small part of the institution; they have simply been the nucleus round which it has grown.

The old church of the priory was fitted up as a laboratory, where machines could be seen in motion, and in which they were submitted to a series of rigorous tests.

In the building near the entrance there was carried out, chiefly under the direction of M. Tresca, the preparatory work connected with the international commission on the *metre*, and not far from the small gate in the Rue St. Martin is the bureau for verifying the weights and measures. The extensive experiments carried out by M. Tresca on the strength and other physical properties of the materials of construction, must be specially mentioned as one of the most useful works done in the Conservatoire. The specimens are tested by a hydraulic machine capable of exerting a pressure of 500,000 kilo.

By decree of 17th February, 1880, M. Hervè-Mangon, member of the institute, and professor of agricultural works and rural economy, was appointed director of the Conservatoire, on the death of Morin.

The library of the Conservatoire is situated in the refectory of the ancient priory, which is one of the *chef-d'œuvres* of architectural art. It contains a rich collection of works relating to science, the arts, agriculture, and industry, to the number of about 25,000 volumes.

After having fully traced the historical development of the Conservatoire, and the

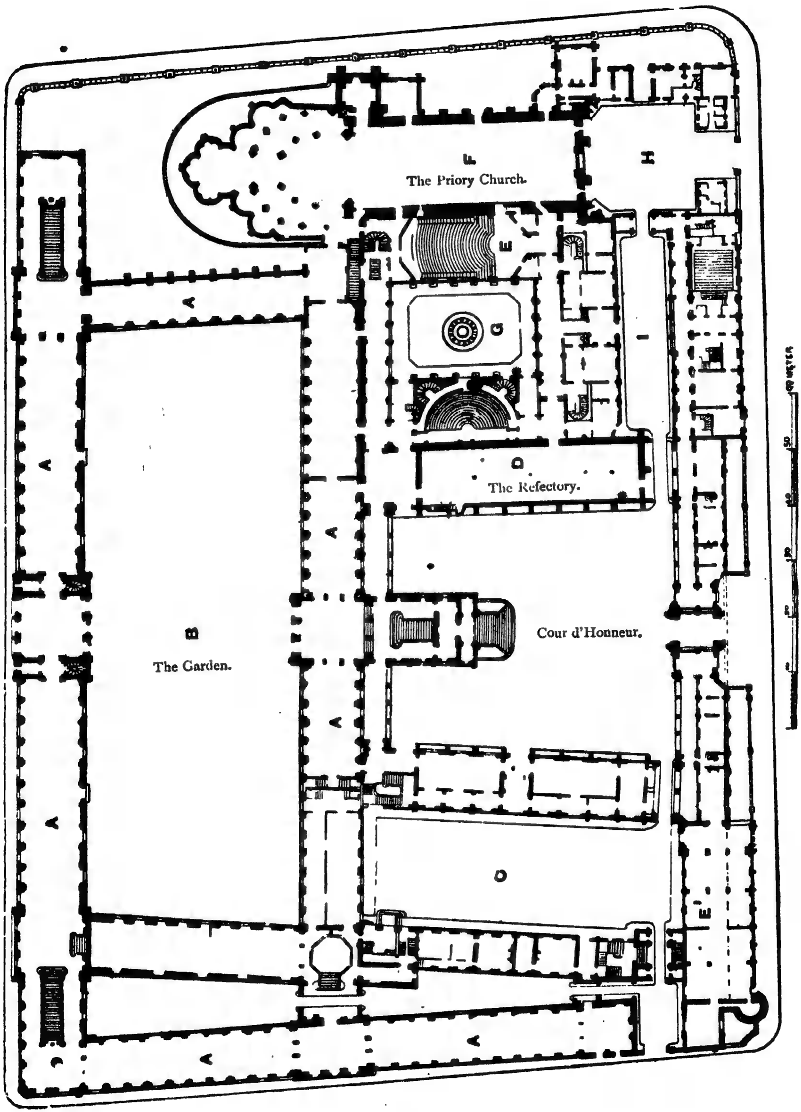

F
The Priory Church.
H
E
G
I
D
The Refectory.
A
B
The Garden.
Cour d'Honneur.
C
E'

FIG. 1.

educational arrangements connected therewith, the editor proceeds to notice the various collections contained in the museum.

"As already explained, the foundations of the museum were laid by Vaucanson, and considerable additions were made during the First Republic, the Consulate, and the First Empire, both by purchases and legacies, and under the Second Empire a large number of historic models were presented by the Academy of Sciences, and by the Society for the Encouragement of National Industry; and the various international exhibitions have always been laid under contribution for some of their most important specimens. Manufacturers and inventors have also, from time to time, presented many examples of their products and models of their inventions, so that the collections are now very complete, not only in modern specimens, but they also illustrate, in a very instructive manner, the gradual development of the different manufactures and classes of machines.

"Passing through the Cour d'Honneur, and into the building by the main entrance to the Salle d'Echo, or the Echo Hall, on the north side we find the galleries devoted to weights and measures, topography, geodesy, astronomy, and horology. This latter section is one of the most complete in the museum, and illustrates the development of time-measurers from the days of the early Egyptians to the present epoch, and, in itself, would require many weeks for its thorough study. Next to the galleries of horology, are a series of rooms containing models and illustrations relating to geometry and the arts of construction in all their departments, and consequently of great importance to the carpenter, builder, architect, and civil engineer. On the south side of the Echo Hall, we have the departments of metallurgy, mining, agriculture, and agricultural constructions and products. The hall with machines in motion is at the southern extremity of this gallery, in the ancient church of the Priory of St. Martin, where, in addition to the older machines, new inventions are continually being exhibited to the visitors, and, in recent years, great interest has been taken in electrical inventions, especially in those relating to the transmission of power to a distance.

"Upstairs, the central hall is occupied with specimens relating to railways, and contains many good models of locomotives and their parts, as well as of railway plant generally. The gallery running along the whole length of the front, contains models of steam-engines and other prime movers, machine tools, and machine parts, to illustrate practical kinematics, and of the apparatus and products of the chief chemical industries. The section on prime movers is particularly interesting, and fully illustrates their development and present designs, hydraulic machines and steam-engines being very fully represented, the mere enumeration of their names occupying about thirty pages of the official catalogue.

"At the extremity of the north gallery are rooms containing specimens of porcelain, glass, and the staining and dyeing of paper and cloth, and various chemical industries, such as paper-making, photography, lithography, &c., and there has recently been added—extending lengthwise—in front of the main building, a large gallery containing many specimens illustrating the industries connected with spinning and weaving; and behind the main gallery are rooms filled with all kinds of physical apparatus.

"The sketch we have given will enable our readers to have some idea of the nature of the various collections in the Conservatoire; but they require to be seen in order that an

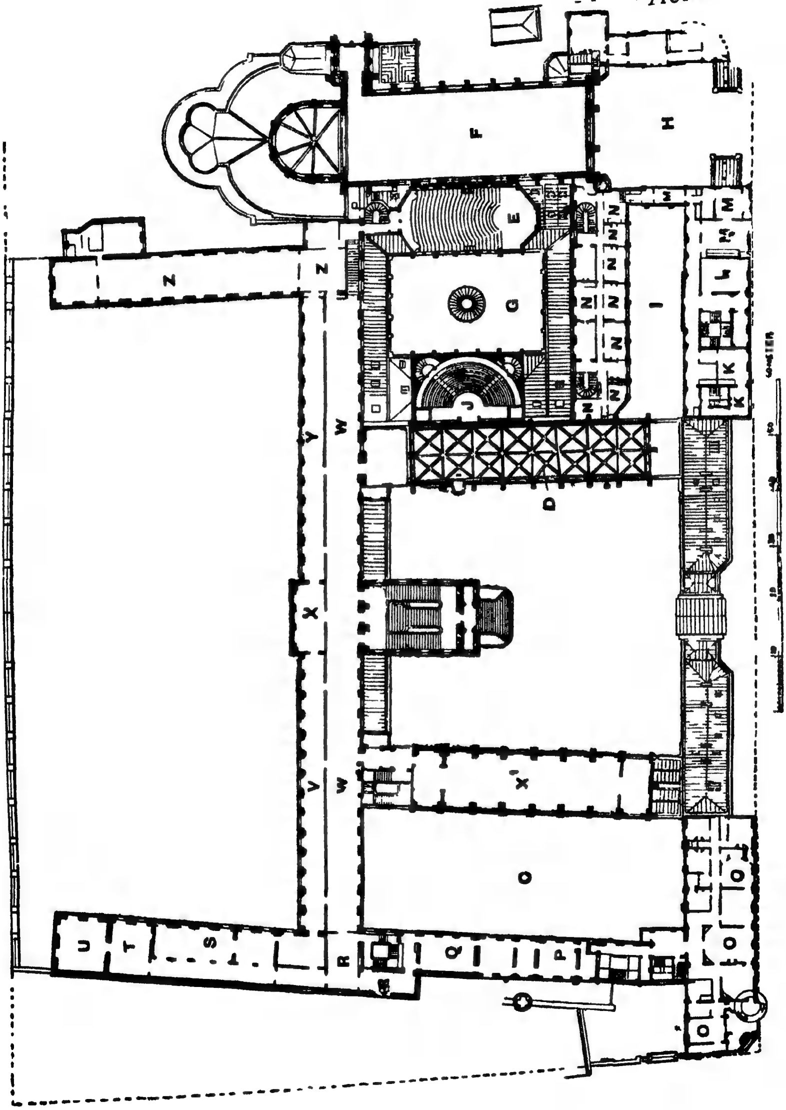


FIG 2

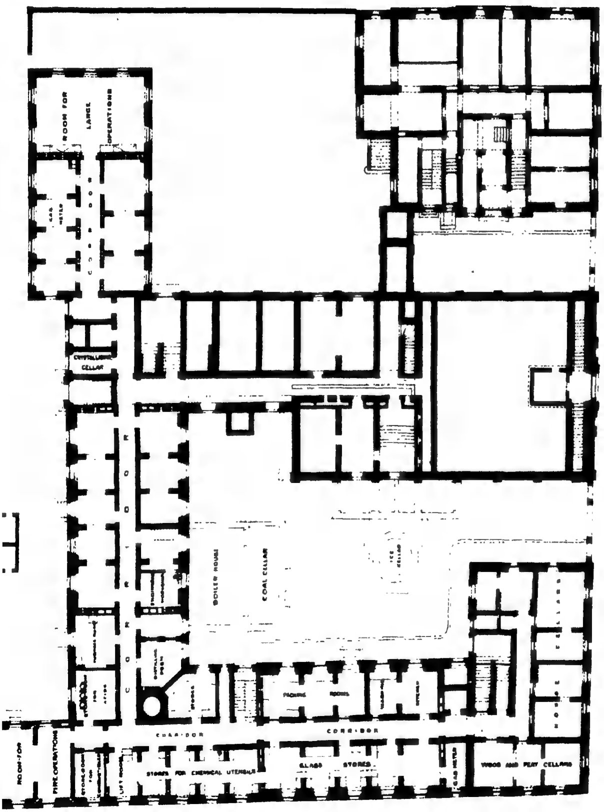
...onception may be formed of their extent, and of the excellence of the specimens ad... they contain. The official catalogue contains fully 500 closely-printed pages of their ...ames. From that catalogue we have copied the plans of the buildings, which will enable our readers to form a general idea of their arrangement and magnitude. Fig. 1 is a ground plan of the institution as it will be when it has been completed; Fig. 2 is a plan of the upper flat of the buildings.

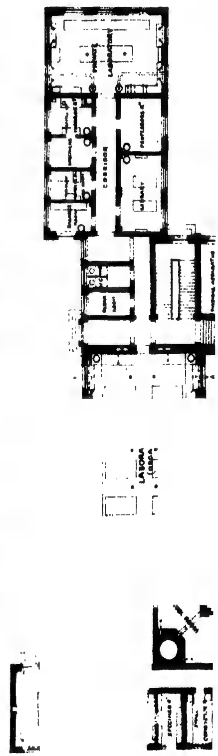
"The distinguishing letters on these plans refer severally to the various departments comprised in the Conservatoire, A A being galleries, B garden, C G H and I courts or quadrangles, D library, E great lecture-theatre, F exhibition-hall, J lecture-theatre, E administrative departments, K K laboratory for agricultural chemistry and chemical analysis, L council-chamber, M M physical laboratories, N N professors' rooms, O O director's apartments, P graphic arts, Q manufacture of paper, R R industrial chemistry and chemical products, S T ceramics and glass manufacture, U dyeing, V motive power, W steam-engines and machine tools, X railways, Y acoustics and optics, Z physics and mechanical physics.

"The Parisians are proud of the Conservatoire des Arts et Métiers, and speak of it as the Sorbonne of Industry. It has done much to justify the use of the title already, and, no doubt, when its connection with the École Centrale des Arts et Manufactures becomes more intimate, as it is certain to do, it will be still more efficient."

Englishmen are not wont to be proud of anything they possess, or they might find reason to congratulate themselves on their South Kensington treasures of industry and art. The reason seems to be that our Government takes so little interest in National Education, and what with the parsimony of rate-payers and public purse-holders, generations pass before decently-designed, permanent, resting-places are found for our overflowing museums and collections. The Brompton boilers still remain to our disgrace, and even the Imperial Institute will not include within its grasp the sites of ruinous sheds and makeshift receptacles of priceless treasures. How can a people be proud of what their rulers ignore, and devote no public money to properly preserve in a stately manner for the national good?

MUNICH UNIVERSIT'



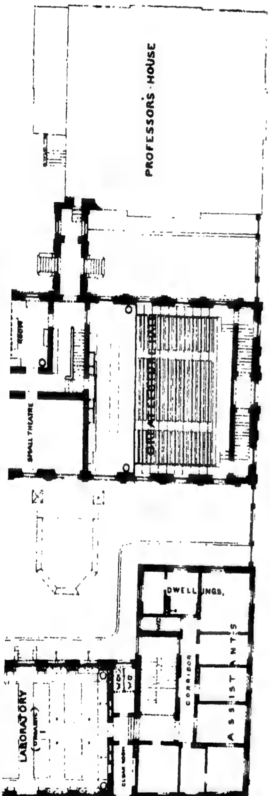


BASEMENT FLOOR PLAN.

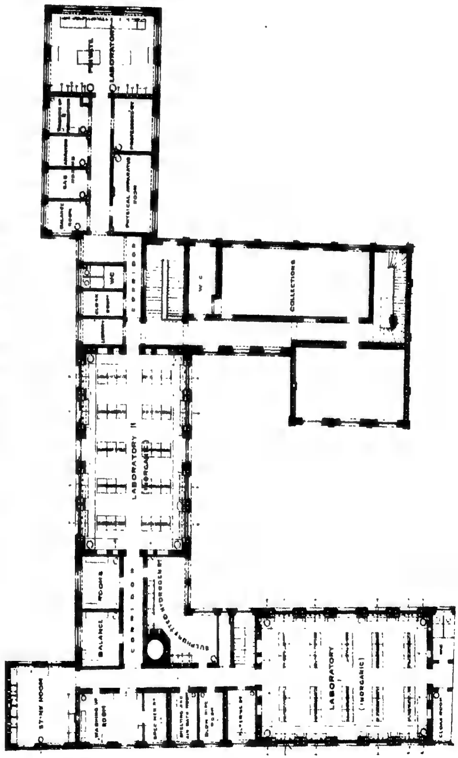
FIG. I.

GF

LABORATORY.



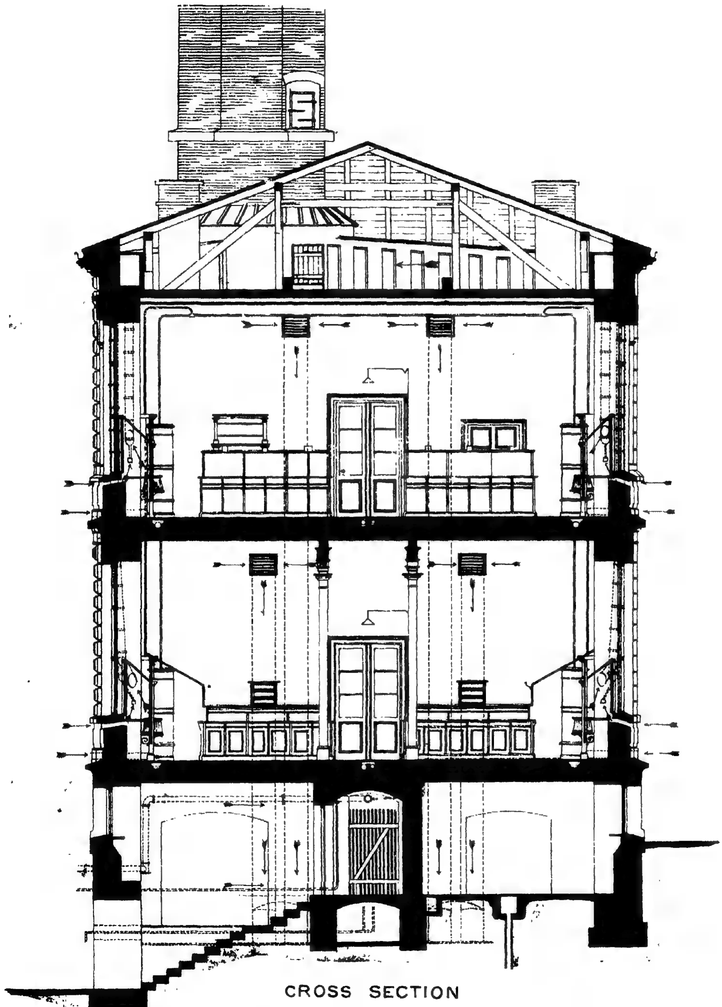
PLAN.



FIRST FLOOR PLAN.

FIG.3.

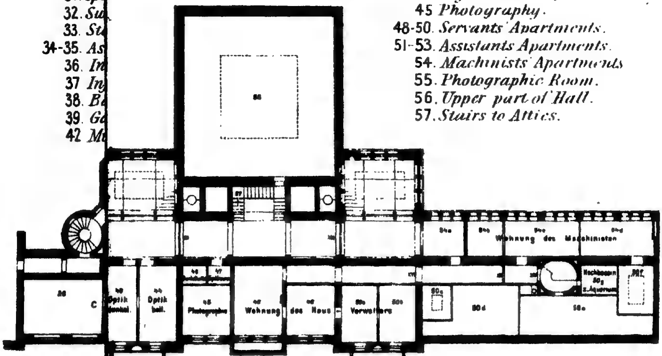
MUNICH UNIVERSITY: CHEMICAL LABORATORY.



CROSS SECTION
THRO. LARGE LABORATORY.

26-30 *Ch*
31. *Sp*
32. *Su*
33. *St*
34-35. *As*
36. *In*
37. *In*
38. *B*
39. *G*
42. *M*

43-44. *Light & Dark Optical Rooms.*
45. *Photography.*
48-50. *Servants' Apartments.*
51-53. *Assistants Apartments.*
54. *Machinists' Apartments.*
55. *Photographic Room.*
56. *Upper part of Hall.*
57. *Stairs to Attics.*



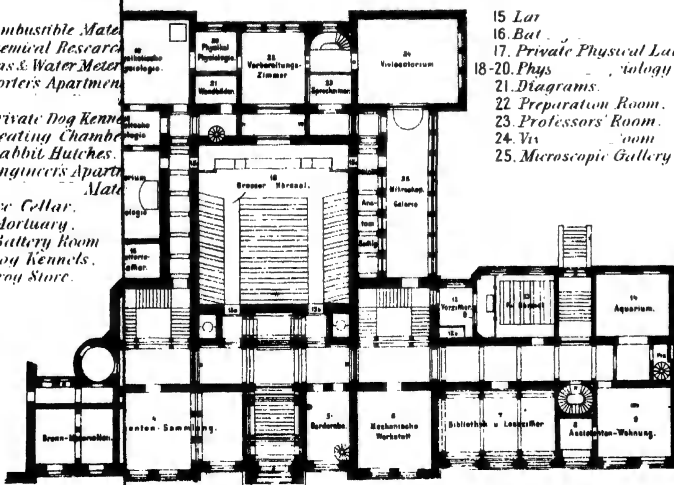
SECOND FLOOR PLAN

FIG. 4.

59. *Combustible Mate*
62. *Chemical Researc*
as & Water Meter
Porter's Apartmen

73. *Private Dog Kenn*
74. *Heating Chambe*
76. *Rabbit Hutches.*
79. *Engineer's Apart*
Mate
83. *Ice Cellar.*
84. *Mortuary.*
5-86. *Battery Room*
7-90. *Dog Kennels.*
91. *Frog Store.*

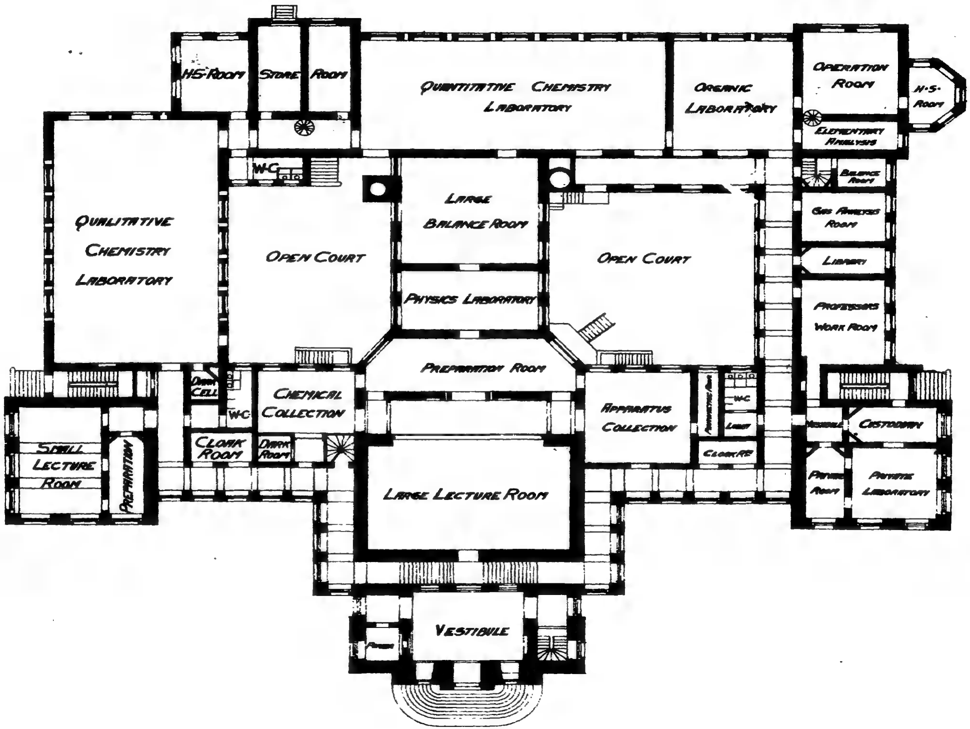
15. *Lar*
16. *Bat*
17. *Private Physical Laboratory.*
18-20. *Phys iology Laboratory.*
21. *Diagrams.*
22. *Preparation Room.*
23. *Professors' Room.*
24. *Vi oom*
25. *Microscopic Gallery & Anatomical Collection.*



GROUND FLOOR PLAN.

FIG. 2.

AACHEN TECHNICAL HIGH SCHOOL; CHEMICAL LABORATORY.

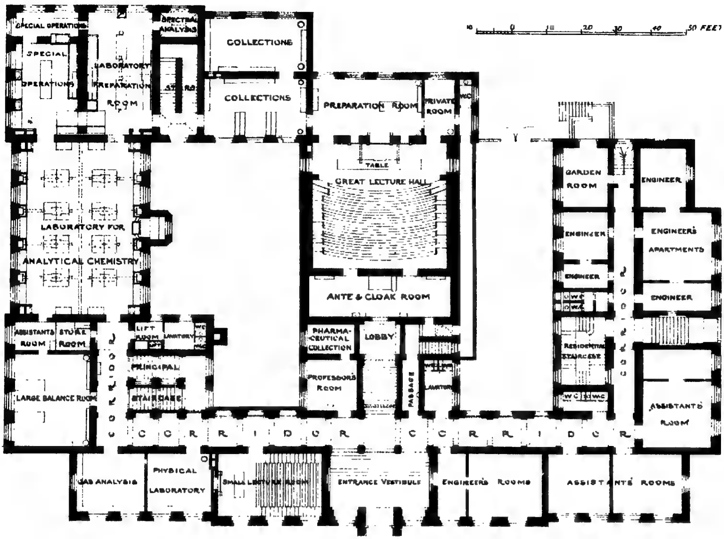


GROUND FLOOR PLAN.

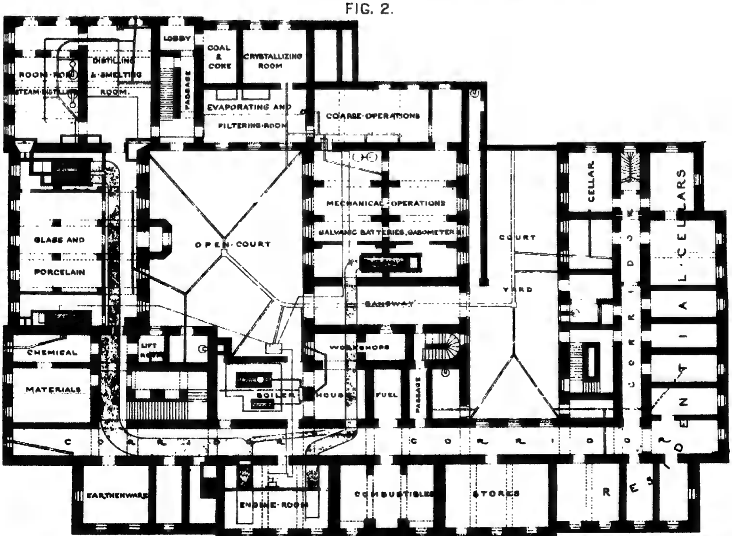
10 0 10 20 30 40 50 FEET.

GRAZ CHEMICAL INSTITUTE.

PLATE 5.

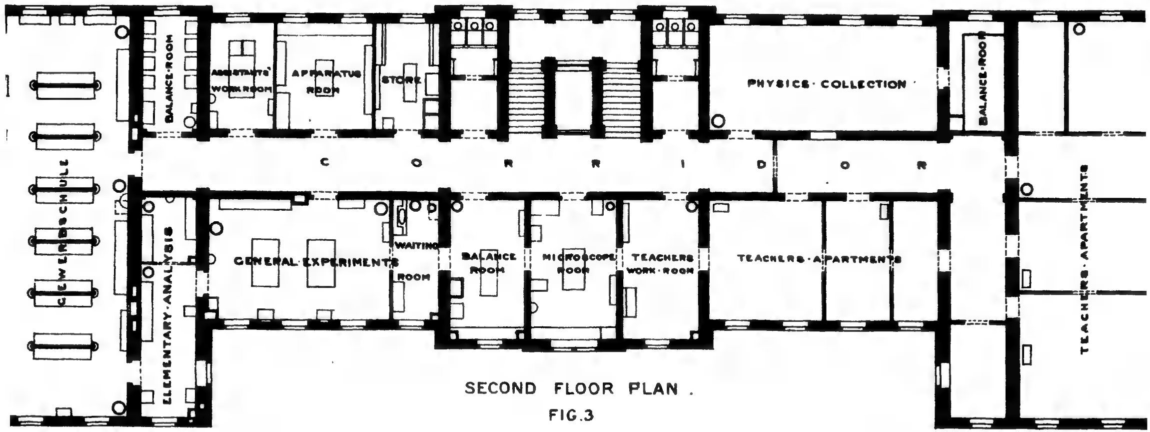


GROUND FLOOR PLAN.
FIG. 2.

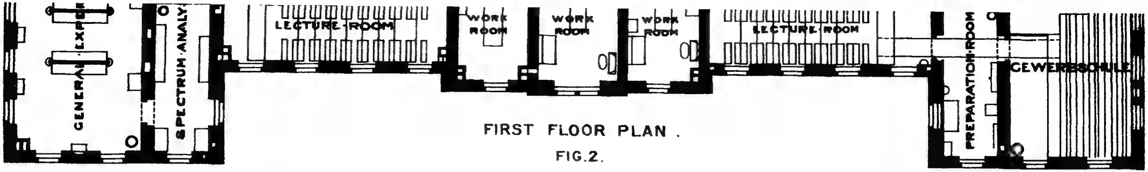


BASEMENT FLOOR PLAN.
FIG. I.

CHEMNITZ ROYAL TRADE SCHOOL

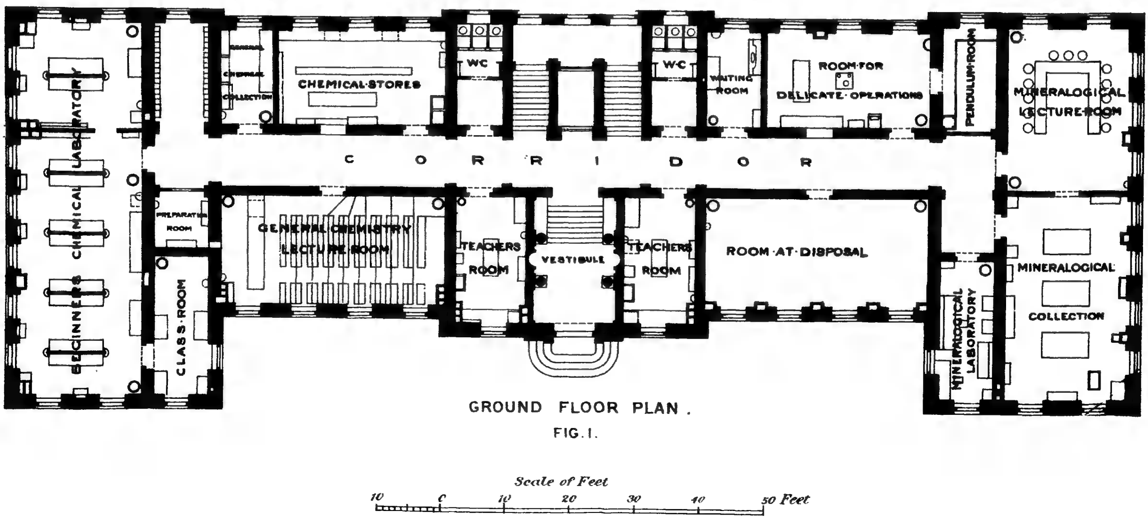


SECOND FLOOR PLAN.
FIG.3



FIRST FLOOR PLAN.

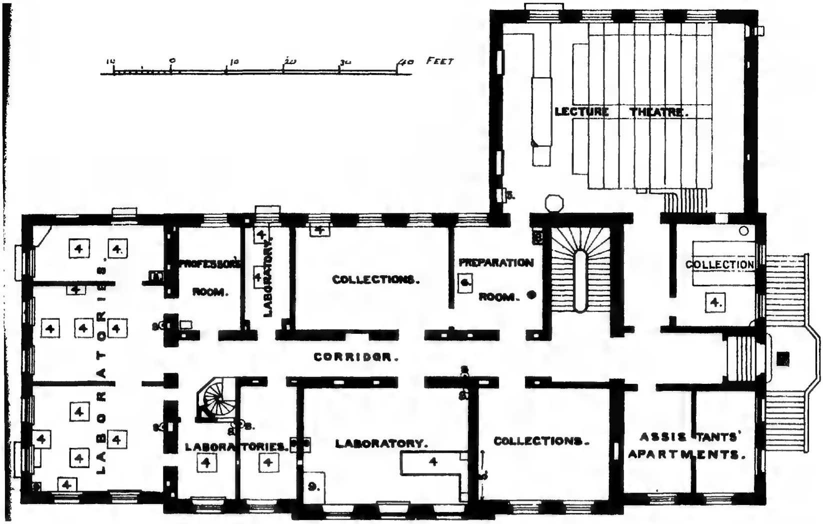
FIG. 2.



GROUND FLOOR PLAN.

FIG. 1.

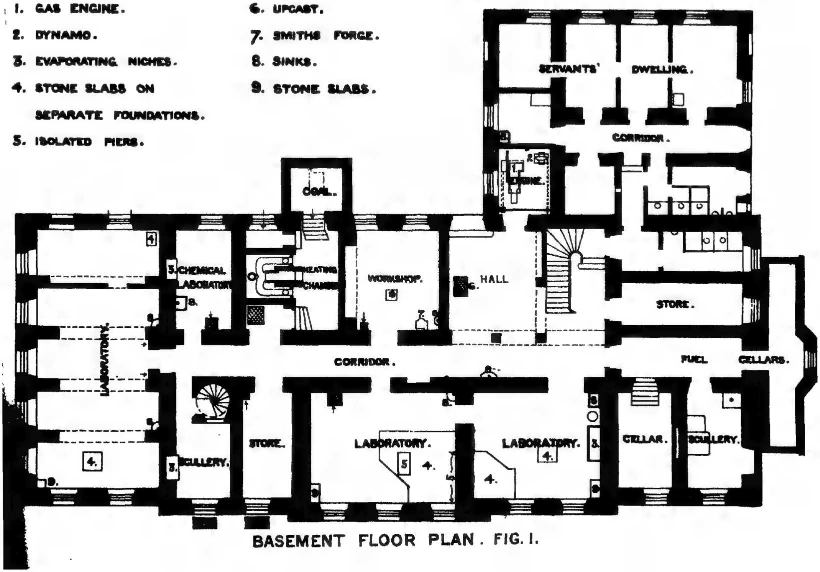
WURZBURG PHYSIOLOGICAL INSTITUTE.



GROUND FLOOR PLAN . FIG. 2.

REFERENCES.

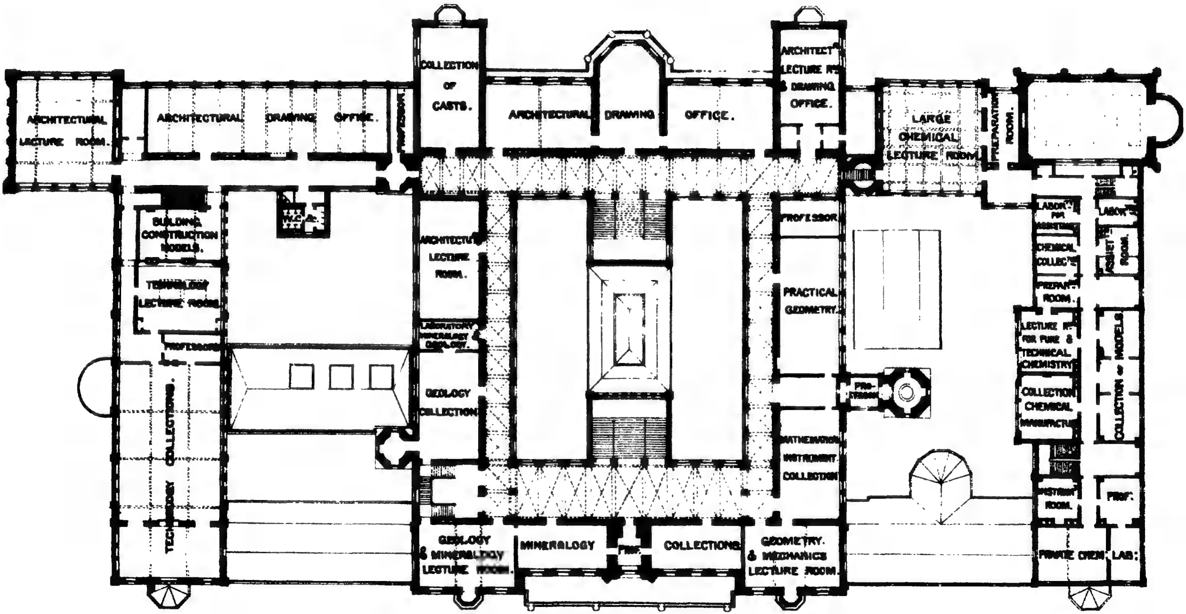
1. GAS ENGINE.
2. DYNAMO.
3. EVAPORATING NICHES.
4. STONE SLABS ON SEPARATE FOUNDATIONS.
5. ISOLATED PIERS.
6. UPCAST.
7. SMITHS FORGE.
8. SINKS.
9. STONE SLABS.



BASEMENT FLOOR PLAN . FIG. 1.

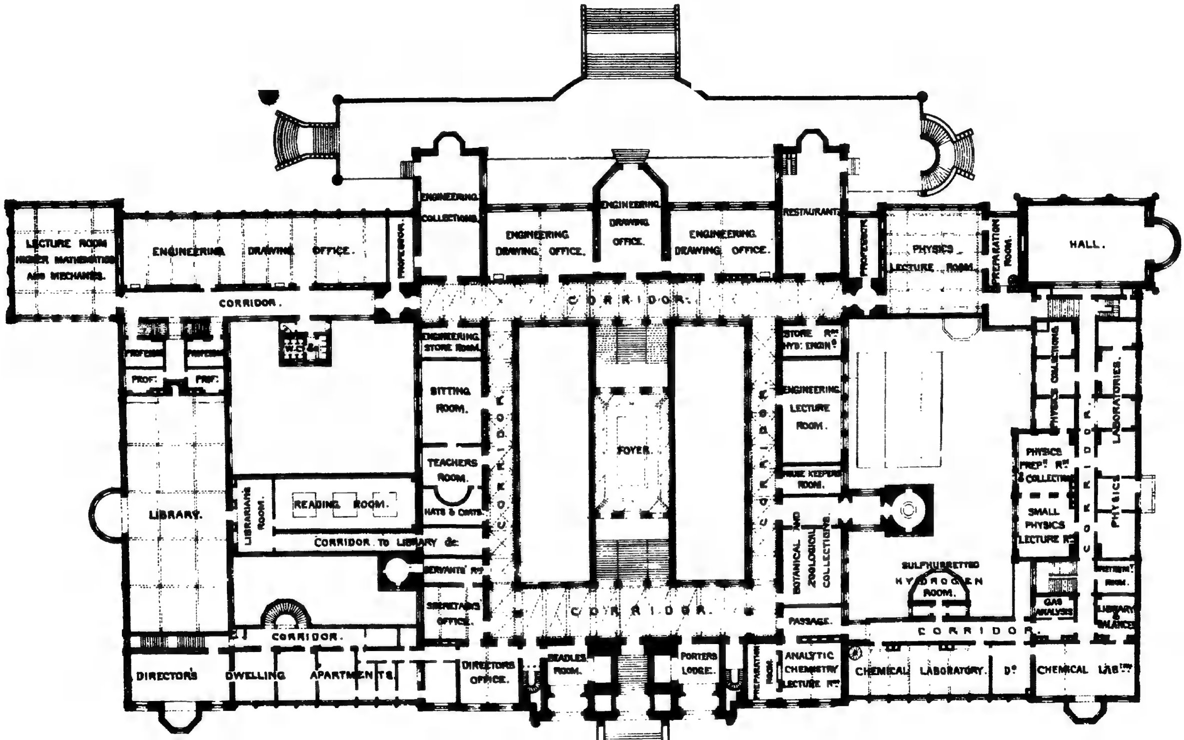
PLATE 8

HANOVER TECHNICAL HIGH SCHOOL.



FIRST FLOOR PLAN.

FIG.2.

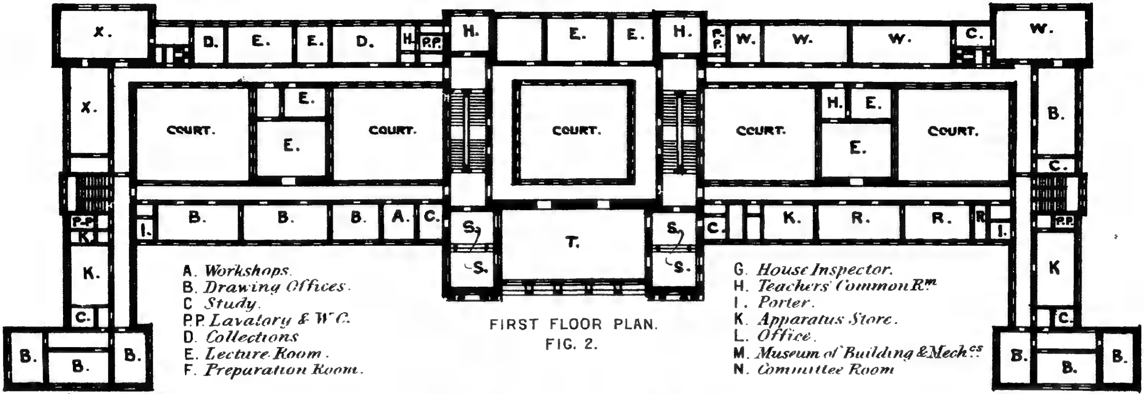


GROUND FLOOR PLAN

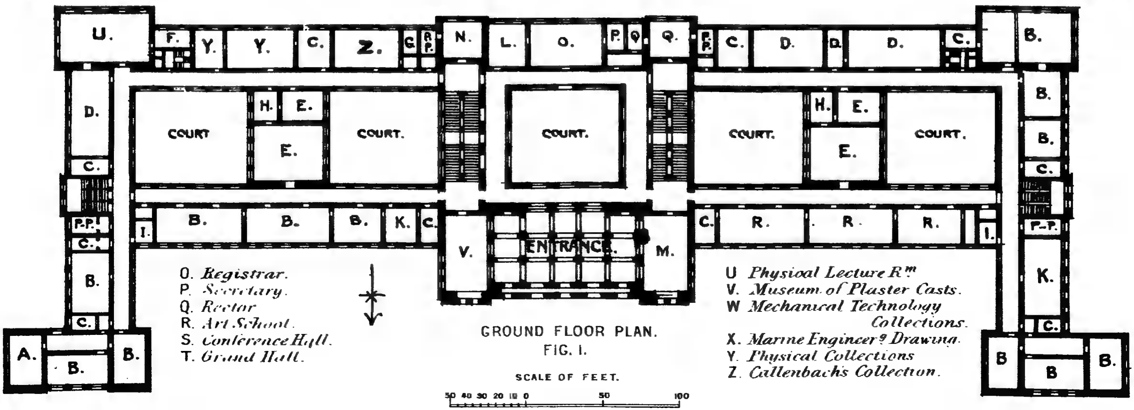
FIG. I.

PLATE

BERLIN ROYAL TECHNICAL HIGH SCHOOL.

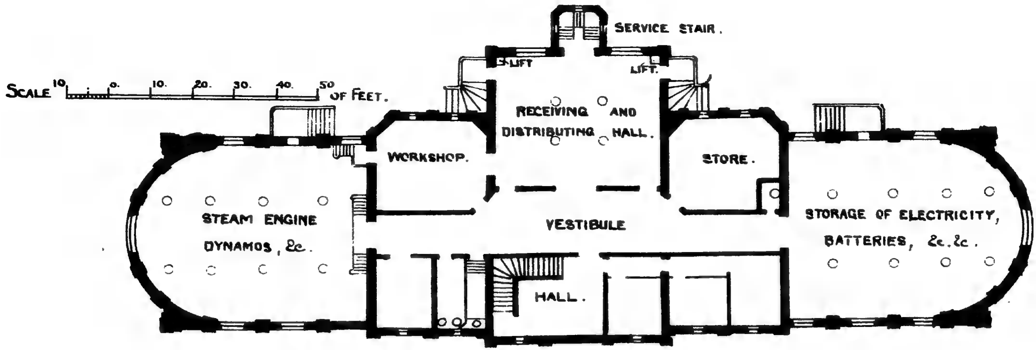


FIRST FLOOR PLAN.
FIG. 2.

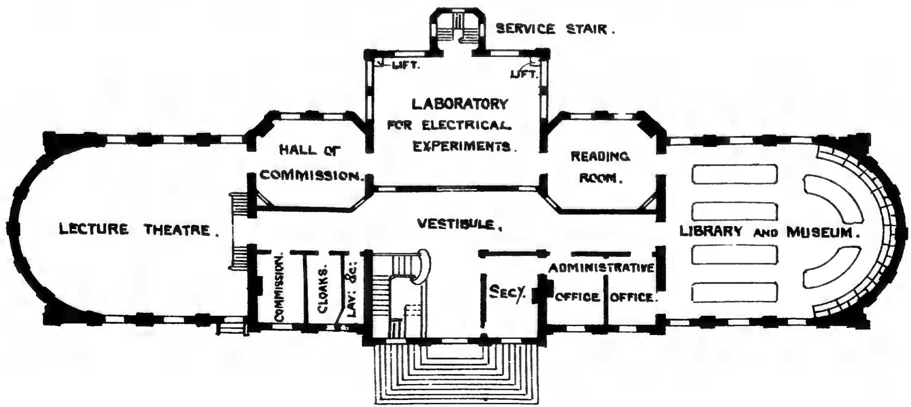


GROUND FLOOR PLAN.
FIG. I.

PROPOSED ELECTRIC ABORATORY. PARIS.



BASEMENT FLOOR PLAN. FIG. 2.



GROUND FLOOR PLAN

CHAPTER IV.

ENGLISH BUILDINGS.

THE examples of English buildings to which attention is called in this chapter, have not, that I am aware of, been separately published, though notices have appeared in scientific journals, such as *Nature*, *Industries*, *The Builder*, &c., &c. The collection in one volume has appeared to me to be the only way of making comparative analysis possible.

The following is a list of the buildings described in this chapter, illustrated by twenty-four plates.

16. The Central Institution, South Kensington, erected by the City and Guilds of London Institute for the advancement of Technical Education (Plates 11 to 13).
17. The Technical College, Finsbury, erected by the same Institute (Plates 14 to 17).
18. The Yorkshire College, Leeds, chemical and physical laboratories (Plates 18 and 19).
19. The dyeing department, ditto (Plate 20).
20. The engineering and mechanical department of the same college (illustrated by woodcuts).
21. The Merchant Venturers' School, Bristol (Plates 21 to 24).
22. The London University College laboratories and art schools.
23. The Manchester Grammar School chemical laboratory (Plate 25).
24. The Oldham Science and Art School and chemical laboratory (Plate 26).
25. The Mason College, Birmingham (Plates 27 to 29).
26. The Liverpool University chemical laboratory (Plate 30).
27. The Huddersfield Dyeing and Weaving School (Plate 31).
28. St. Thomas's Hospital medical school (Plate 31).
29. Owen's College, Manchester, medical school (Plate 32).
30. The Oxford University physiological laboratory (Plate 33).
31. The Cambridge University chemical laboratory (Plate 34).

16 THE CITY AND GUILDS OF LONDON CENTRAL TECHNICAL INSTITUTION, SOUTH KENSINGTON. (Plates 11, 12, and 13.)

The drawings for this magnificent enterprise are particularly deserving of study. The architect of the building has developed the intentions of the Executive Committee in the broad spirit in which they were conceived. In this case not only have the professors of the Finsbury College lent their aid, but the presidents of the Royal Society, of the Institution of Civil Engineers, of the Chemical Society, and of the Society of Arts have each acted on the sub-committee, to whom the arrangements of this building have been specially entrusted under the presidentship of Sir Frederick Bramwell, whose untiring labours have mainly contributed to the remarkable success of the institute. But to the great experience of Mr. Alfred Waterhouse, R.A., to his personal supervision of details, and his adoption of the latest improvements in fittings and in heating and ventilation, we chiefly owe one of the most efficient technical colleges of modern times. Illustrations are given of the basement and ground-floor plans, and of the northern halves of the second and third-floor plans (see Plates 11 to 13).

The building has a frontage of 300 feet and a depth of 120 feet. The main front building is five stories in height; the north-western wing is 80 feet wide, and four stories in height; the south-western wing is postponed for the present. In the rear of the central portion of the main front is a single-story top-lighted workshop, 100 feet long by 50 feet wide. The main staircase is in the centre of the building, and a 10-feet wide corridor runs right and left the whole length of the building. The west wing is divided by a central corridor at right angles with the main corridor, connected by the northern staircase, on the south side of which is the great chimney, next lift, 120 feet high, and the chemical upcast shaft with extract-fan at top.

The special subjects to be taught technologically are limited to engineering, physics, mechanics, chemistry, and art, as chiefly required in industrial art development.

With the exception of one room the whole of the basement, ground, and first stories of the front building, situated on the southern side of the main central entrance, is devoted to physics, which for the present will share with engineering one of the lecture-rooms in the north-western wing.

The remainder of the basement and ground floor is devoted to engineering and mechanics. The chemistry and physics lecture-rooms are in the north-west wing.

On the first floor over the main entrance is the reading-room and library, and the remainder of the north end of the main building is devoted to administrative offices and the council-chamber. The whole second floor of the main front building, except the four northernmost rooms, is devoted to art and mechanical drawing. The remaining rooms on this floor and on the next, as well as on the two upper floors of the western block over the lecture-rooms, are given up to chemistry. The museum is on the top of the central block.

Third-floor plan (Plate 13, Fig. 2).—On the western side of the northern staircase is the chemical laboratory, for junior students, which is 78 feet long by 30 feet wide, extending the width of the north-western wing. The lift and the great upcast

ventilating-shaft are on the south side of the staircase, beyond which are the photographic and photometric dark rooms suitable for experiments. (A small staircase leads to the flat roof for out-door operations.) On the north side is the gas analysis and the thermo-chemical laboratory; in the north-east corner is the large balance-room with a large drawing-table in the middle, and benches and glass cases round; in the east is the polariscope room, and rooms for stores. The positions of the various fittings are shown on the plans and the space they occupy, their purposes are indicated by letters the key to which is given in the reference table on the left side of each of the plans.

Some of the details of the fittings of the laboratory are given in illustration of the chapters on fittings (see Plate 40). The four double operating benches and their large draught-closets are set transversely and parallel with two long tables and a bottle rack. Benches and draught-closets and sinks surround the walls. The ripened experience of Dr. Armstrong may be traced in the excellence of the fittings in the chemical department, which were all carefully planned by him.

Second-floor plan (Plate 13, Fig. 1).—Two large chemical laboratories—each 50 feet long, the one 35 feet wide, the other 31 feet 6 inches—occupy the western wing, and are fitted up in the manner shown, and intended for advanced students devoting themselves especially to higher chemical studies. The corridor between them is utilised as a combustion-room, and on the north side of staircase is the electro-chemical laboratory; on the south side is a room for experiments involving bad smells, entered by an external balcony landing from corridor.

On the east side of the corridor is the chemical professor's room and special laboratory, 35 feet by 28 feet, and a chemical room for small classes. The rest of this floor is devoted to art classes.

First-floor plan.—No illustration is given of this floor. The students enter the upper part of the two lecture-rooms at this level on the north side of north staircase. The eastern side of main corridor, beginning at the northern end, has a council-room, waiting-room, assistant secretary's room, director's room, and clerks' room, all communicating with each other and the corridor. Beyond the central library and reading-room and main staircase are rooms of the physical department devoted to a laboratory for experiments on heat, another for experiments on magnetism, a third for experiments on sound, and the fourth, at the south end of the building, is the electrical laboratory for first year students.

Ground-floor plan (see Plate 12).—The western wing is occupied by the chemical and physics lecture-theatres, the latter being available for lectures on engineering in the event of there being a very large class in that subject. Preparation-rooms are provided for each, fitted up as shown. Professors' and assistants' lavatories, &c., are situated between the western block and the central staircase. On the east side of corridor at the northern end is the mathematical drawing-room and class-room and professor's room, also the mathematics and mechanics lecture-room. On one side of the great central staircase is the professor of engineering's room and apparatus store, and on the other side his small lecture-room. At the southern end of the corridor are three physics rooms, viz., a class-room, the professor's room, and an optical laboratory.

Basement-floor plan (see Plate 11).—Descending to the basement by the small south staircase, where there are two lifts opening on the landings of each floor, we arrive at the two rooms for physics delicate experiments, well provided with solid brick-tables on concrete bases, of which there are some sixteen. Beyond there is a room for advanced experiments in heat, two small workshops for wood and metal, in which apparatus is constructed for special investigations in the physical department and repairs of physical apparatus conducted. Under the central entrance-hall is a large room for students' lockers, and a long, dark room for photometric work, &c.

Under the physics lecture-room at the northern end of the basement, and therefore well removed from the rooms for the delicate electrical experiments, which are situated at the south end, there are two rooms. The one is a dynamo-room fitted with an eight-horse power, nominal, engine and boiler, which drives one dynamo-machine directly, and also two lines of shafting fitted with large conical pulleys. Each set is for driving one dynamo, and by shifting the belt along one of the sets of pulleys the speed of any one dynamo can be varied at will without affecting the speed of the others.

Dynamo-meters attached to the dynamos record the power required to drive them, and the currents they produce are sent to all parts of the physical department. In the adjoining room is fitted apparatus for experiments on electric lighting, electric motors, transmission of power, &c. A number of accumulators for supplying perfectly steady currents to all parts of the physical department, as well as for experiments on the electrical storage of energy, are also in these two rooms.

This ends the physics department, which has been fitted from the designs of Professor Ayrton, whose previous experience at Finsbury and at Japan give great value to all the arrangements made for this department.

The rest of the basement is devoted to mechanics and engineering. On the south-west is the engineering drawing room fitted with twenty tables, adjoining which, and behind the central staircase, is the engineering workshop and laboratory. These three rooms are covered with glass roofs. The workshop is fitted with four lathes, two shaping machines, three drilling machines, one tool-grinder, one planing machine, a large central bench, and a long wall vice-bench. The laboratory has also a wall vice-bench, two long tables, and a powerful testing machine.

The vice-benches are continued into the engine-room, adjoining which is the boiler-room, up- and down-cast shafts, the store-room, and the fan chamber with open area adjoining, and students' lavatory.

Professor Unwin (the Dean of Studies), under whose instructions the engineering and mechanical laboratories have been so admirably fitted up, brought with him his experience gained at Cooper's Hill College. It is to be expected, therefore, that the fittings of the Central Institution are likely to be models of their several kinds, owing to the fact that this institution has had the benefit of being fitted up by such specialists as Professors Unwin, Armstrong, and Ayrton.

At the north-east corner is a large joiner's shop, and a smaller one next it. The next room forms a passage-way to the vaults under the pavement along the east front area. Between this passage and the central staircase are two mechanical workshops.

The heating and ventilation of this building are fully described in the chapter on

heating and ventilation. Steam is the heating agency, and the fresh air is propelled by a fan over the steam-heaters in the wall-chambers arranged in the basement, and through the horizontal and vertical shafts supplying the various rooms.

17. THE TECHNICAL SCHOOL, FINSBURY. (See Plates 14 to 17.)

This building was completed at a cost of 36,000*l.* It is the first important work of the City and Guilds of London in point of time—if we except the Kennington Art Schools under the care of Mr. Sparkes—and it represents a model of the kind of structure which should be within the means of every important provincial town. Originally designed as a trade school, it has developed into a technical or applied science college for working men and apprentices. Chemistry and physics were first provided for, but ultimately mechanics was added, and the Professors Armstrong, Ayrton, and Perry have done the best they could with the limitations prescribed by the only available site abutting on Tabernacle Row on the one side, and the playground of Cowper Street Schools on the other. The architect of the building is Mr. E. N. Clifton. The present principal is Professor S. P. Thompson, who teaches physics, while Professor Meldola takes chemistry, and Professor Perry, mechanics and mathematics. The general arrangement of the building is as follows:—

On the second floor (Plate 17) the iron staircase occupies the centre of the place. The great chemical laboratory occupies the east side, and is divided by two iron columns into senior and junior laboratories. The senior students are on the south side, with five double benches down the centre of the room and wall-benches next the south wall. On the north side are the junior students' detached benches and wall-tables; and the demonstration-table and platform are on the east side.

The hooded draught-flues from these tables supersede special stink-closets. On either side of the great chimney-shaft are the exit doors to landing, from which on the north side is the balance-room with its stone wall-brackets, &c., and on the south side is the demonstrator's room. The adjoining small staircase leads to the flat roof. Beyond the staircase are the conveniences for students.

At the western end of the landing, on the south side, is the chemistry professor's room, out of which is his laboratory and room for special operations, carefully fitted with working benches, sinks, draught-closets, &c. The chemical glass store and the re-agent store-rooms come next. There is also a large class-room, between which and the balance-room is the gas-analysis room.

On the first floor (Plate 16), under the chemical laboratory, are the two large lecture-rooms, one for physics and mechanics, the other for chemistry, with the students' common-room under the upper part of galleries. Each lecture-room has its preparation-room adjoining, and glazed opening in centre behind lecturer, giving access to same for apparatus, besides the door of communication. There are foul-air shafts and floor draught-channels in connection with the lecturer's tables and preparation-rooms. At the western end are rooms for experiments on light and for mechanical engineering, adjoining which is a physics plan-drawing room.

On the ground floor (Plate 15) is the entrance to the building from Tabernacle Row,

under a stone portico, and opposite the vestibule is the great central staircase with landings on its three sides. On the right of the entrance are rooms for the secretary and the clerks; next which are the mechanics professor's room and the physics workshop with class-room adjoining, fitted with Moss's patent benches. At the north-east corner is a mechanical-drawing office, and a physics laboratory adjoins. At the west end are two physics laboratories, and the physics professor's private room, which is also the principal's room. Seven steps below level of ground floor and lined with white glazed bricks is the chemical brewing and large operation-room.

In the basement (Plate 14) under the brewing-room and five steps below the general basement level, are the heating furnaces and boiler-room, and the heating chamber, fitted with wrought iron hot-water pipes, the fan being at one end of the room and the channel flues at the other. West of this room is a dynamo-room with gas-engine, adjoining which is the physics store-room, with a brick wall to carry stone-tables above. At the south-west corner is the chemistry gas-testing room, adjoining which is the metallurgical laboratory.

The eastern half of the basement is devoted to mechanics: first a general laboratory or class-room, then a wood workshop, then an iron workshop, and finally the engine-room with fourteen-horse-power condensing engine and multitubular boiler.

This engine not only turns the shafting, but provides the power for working the dynamo for producing the electricity with which the building is lighted, and the electrical experiments are carried on in connection with all the laboratories. There are areas at the back and in front with a series of vaults under the pavement. A metal-plate working-room and a plumber's working-room is also provided on this floor. The whole of the basement is lined with white glazed bricks.

18. THE YORKSHIRE COLLEGE, LEEDS. CHEMICAL AND PHYSICAL LABORATORIES, &c. (See Plates 18 and 19.)

This comprehensive scheme is being gradually worked out, and when completed will be one of the noblest institutions of the kind; it is already far advanced, and must be considered as one of the latest and best outcomes of what is thought to be a fitting provision in buildings, fittings, and apparatus for the applied science teaching of to-day.

The weaving and dyeing schools, through the munificence of the Clothworkers' Company, were the first to be built, and then the three sides of the irregular quadrangular building, designed for the accommodation of chemistry in all its branches, physics, biology, and metallurgy, to which has been added an engineering department admirably equipped. Fine art and modern languages are only temporarily accommodated till the remaining portions of the buildings are erected.

The centre of the quadrangle is destined to be the museum of specimens, models, and apparatus required for illustrating the lectures delivered upon the various arts and sciences, to the teaching of which the building is to be devoted, and for students' reference. This central museum gives the key-note to the plan. It is an inexpensive way of obtaining what is never absent in Continental examples and rarely present in our own. It is not improbable that this museum will need to be erected

prior to the fourth side of the quadrangle and its wings, which are intended to provide the permanent administrative chambers, the library, and the arts department; the main entrance will eventually be situated at the south-east angle of this block.

The masterly planning of Mr. Waterhouse has been chiefly inspired by Dr. Thorpe, sometime professor of chemistry, and his professional associates, by whom the various requirements have been carefully considered, and after several years of anxious thought and patient comparison with previous examples both English and foreign, the numerous problems, so difficult to solve, have been worked out in a remarkably able manner. The irregularity of the site has provoked an original treatment of the plan and great picturesqueness of exterior design, which, however, has in no way injured the interior convenience.

The building is admirably heated and ventilated, and has realised the expectations which were formed of it. It is heated by steam, the fresh-air inlets passing the air through the steam-heated boxes situated at every window back. A point in this building is the distribution of steam throughout, not only for general heating purposes or for turning the shafting for machinery and dynamos, but for chemical laboratory operations, evaporating and drying-closets, &c.

The ventilation is by shafts in which the draught is actuated by extracting fans.

The accommodation is as follows, which, taken in connection with the illustrations given of the ground and first-floor plans, will be sufficiently clear, more especially since the position and description of the fittings are also indicated on the plans.

Ground plan (Plate 18).—On the right hand of the present chief entrance is the chemical lecture-theatre 65 feet long by 37 feet wide, capable of accommodating nearly 400 students, with amply fitted lecture-table 21 feet in length, behind which are the draught-closets, the black-boards, and diagram frames, capable of being let down through a slit in the ceiling from the diagram-room over this end of the lecture-room; under this lecture-room is a large store-room and space for biological museum, also other store-rooms and porters' apartments. The table in the large draught-closet is movable and can be passed into the lecture-room, or into the preparation-room immediately behind it, which room is fitted up with the usual appliances, glazed cases for chemicals and various apparatus, a working-bench, draught-closet, sink, &c. A lift is in one corner, an external exit-door at the other, while a central door communicates directly with a chemical museum and a chemical store-room.

On the left of the principal entrance, in front, is the present secretary's room, the council-room, and the principal's room, ultimately to be used for cloak-room, tutorial class-room, for organic chemistry and demonstrator's room. At right angles to this southern corridor, giving access to these rooms, is another corridor six feet wide, with rooms on either side of it. On the western or left side, are the special laboratory, the organic chemistry special laboratory, the special laboratory combustion-room, and the metallurgical laboratory. The fittings in each of these rooms are indicated on the plan.

On the right side is the kitchen and the temporary students' dining-room, intended for a work-room in connection with the large central museum, the chemical museum already referred to, and photometric room with blackened walls, now used as store-room. At the end of this corridor, next kitchen, is the smoke-shaft and the great ventilating-shaft.

We have now arrived at the third or northern side of the quadrangle facing Clavering Road. A wide corridor extends the whole length of it, the staircase and communication with the new engineering laboratory is situated at the extreme left, next to which is the students' cloak-room and common-room, and the arts professor's room, the rest is devoted to physics. The physical research workshop adjoins the thirteen-feet wide cartway entrance from Clavering Road, which will ultimately give access, through this northern corridor, to the central museum or general scientific collection. East of this entrance cartway, the physics lecture-room, preparation-room, and laboratory succeed one another, and their fittings are shown on the drawings, including stone wall-tables on stone brackets.

A draught-place and glazed hot-closet are provided between the preparation-room and the lecture-room; the lecture-table has a stable foundation of piers and arches, with a concrete floor behind it. To avoid magnetic influences deranging the delicate experiments carried on here, no iron is admitted into the construction of this room, even the heating pipes are excluded from the laboratory and preparation-room, and the warm air is conducted by special flues. Special arrangements under the control of the professor are made for darkening the room and exhibiting diagrams.

A staircase from the preparation-room communicates with four other rooms in the basement, also devoted to physics, and fitted with similar wall-tables and brick-borne flags for experimental purposes.

First floor (Plate 19).—Returning to the large chemical lecture-room, on the southern front, at the level of the first floor is a cunningly devised room, over the lecturer's end of the room, for preparing, storing, raising and lowering diagrams, somewhat similar to the arrangement at Graz. The curator's room for geology is at the top of the stairs over the preparation-room. The library and reading-room, and chemical professor's room, occupy the southern side of the corridor, and in the centre of the northern side is the entrance to the main chemical laboratory, which occupies the whole of the space between the northern and southern frontages, forming the western block, 62 feet long and 59 feet wide. It is divided into elementary and advanced students' laboratories by a row of five columns, similar to Finsbury College, and not separated by a wall as at Owen's College. This arrangement has come to be considered the best. This laboratory is the finest in the kingdom and is well worth a visit.

The operative benches for quantitative and qualitative chemistry students are arranged at right angles with the dividing line of columns, and with the wall-benches provision is made for about fifty students. The demonstrator's table and chemical dispensary are at the northern end. The western corner is partitioned off, with glazed partitioning, for a steam-engine to work the vacuum pumps at the laboratory benches, and a still-room, outside of which is a sand-bath. The sulphuretted-hydrogen room occupies the northern corner next the great up-cast ventilating-shaft; outside is a large draught-closet and two sinks on a special working-bench; eight draught-closets are situated between the flank windows, four on each side; there are no fume-closets on the students' operating benches, an exceptional arrangement. There are skylights on the open roof of this laboratory.

Re-agent shelves and drawers are fixed against the east wall. On the south wall, on either side of the entrance-door, are the evaporation niches, and beyond them, on the same wall, the distillation apparatus. Details of these fittings are given in illustration of the chapter on the fittings required for science laboratories. (See Plate 48.)

We now enter the northern corridor. Adjoining the north-western staircase, with the W.C.'s and lobby thereto in its rear, is the gas-analysis room, the re-agent store, the balance-room and reference-library, with northern light, and within close proximity to the main laboratory. The coal-mining and temporary art lecture-room comes next; the professor's room jointly used with the lecturers on modern languages, who also share the lecture-room adjoining, and the physics, coal-mining, and diagram-room. At the extreme eastern end is the optical laboratory, with special arrangements for darkening and isolating sections of the room. A professor's room adjoins, from which a staircase descends to the physical rooms below.

Second floor.—Over the large chemical lecture-room in the southern block is the biological lecture-room and laboratory, the passage leading to the same being temporarily used as a biological museum; ultimately the present room will be devoted to the biological lecture-room, beyond which, when the College-road side is completed, will be situated the biological laboratory. The biological professor's room is entered from the corridor and from the landing of the stairs. The remainder of the southern block is occupied by the medical students' room and laboratory in one, a special arrangement which has been found of great service in the teaching of the sciences to large bodies of students by class or oral instruction.

The intervening western block is wholly given to the upper part of the great chemical laboratory. At the west end of the northern block, reached by the north-western staircase, is the chemistry professor's private laboratory and balance-room, at present given up to ladies' retiring-room and common-room, ladies being admitted as students to this college.

The rest of this block was temporarily used by the engineering and arts lecture-room until the erection of the new engineering school, already referred to, as one of the best-fitted of modern mechanical laboratories.

19. THE DYEING DEPARTMENT OF THE YORKSHIRE COLLEGE. (See Plate 20.)

So far as I have seen, the dyeing school at the Yorkshire College is the most complete, both in plan and general equipment. I have therefore chosen it as the best example. It was erected under the special supervision of Professor Hummel, and is full of ingenious ways of accomplishing the ends proposed. It adjoins the weaving schools, which are excellent in their way, and is a two-story building in so far as it is finished. A yarn dye-house of one story in height is yet to be erected.

Ground-floor plan (Fig. . 1).—On the left of the entrance-hall and staircase are three rooms, a lecture-room, a preparation-room with table, cases, draught-closet and sink, a diagram and pattern-room fitted with tables, cases, drawers, &c. The corridor, at right angles to the entrance-hall, gives access to a museum fitted with glazed cases; a printing-room with tables and drawers, printing machine, cases, drying-horses, sink, &c. A colour-

making room with jacketed steam-pans for mixing colours, printing liquor jars, steaming chest, small bleaching kier; sink, tables, drawers, &c., and a lavatory next the great up and down-cast ventilating-shafts. Beyond this the yarn dye-house is to come.

First-floor plan (Fig. 2).—Ascending the stairs to the first floor, to the right of the landing is the large experimental dye-house, admirably ventilated, which is fitted with wall-tables, drawers, and cupboards under a draught-closet; two drying stoves for eight horses, provided with glass rods on which to hang the dyed patterns; six steam-pans for washing operations, and three large working-tables fitted up with porcelain dye vessels. On one table they rest loosely on water-baths provided with steam and water inlets, they are intended for dyeing silk, cotton, leather, or wherever a steady, low temperature is required. On the other two tables the dye vessels are fixed in separate oil-baths, and arranged in groups of three, in high-pressure steam-heated cases made moveable for discharging, and capable of being rapidly filled with hot or cold water without leaving the table, in the manner shown in the details (Plate 49) given in illustration of the chapter on fittings generally. These are intended for dyeing wool, or wherever a boiling heat is required.

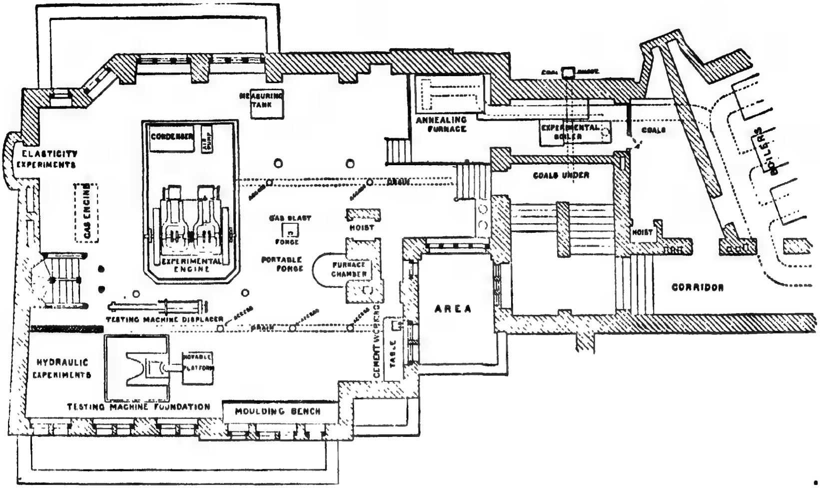
On the left of the landing is the professor's private room, laboratory, and balance-room. The laboratory is fitted with working-tables and sinks, two draught-closets, evaporating-closets, drying-chambers and sand-bath, also blowpipe and combustion-tables; on the other side of professor's room is the store-room and student's balance-room with tables, drawers, cupboards, shelves, and glass cases, in the positions shown.

20. The Engineering Department of the Yorkshire College. (See woodcuts.)

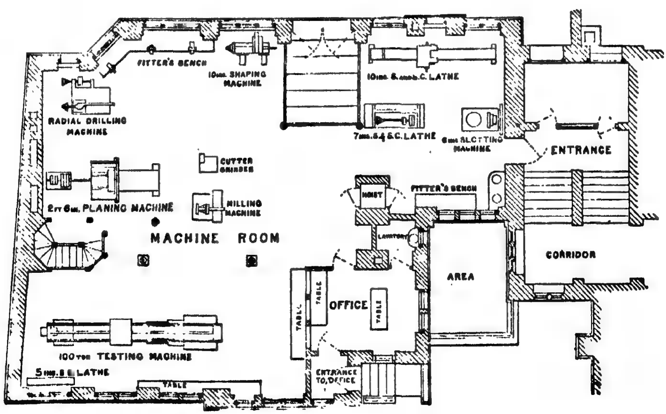
This building, which is of brick with stone facings, has an elegant frontage in keeping with the other parts of the college. It forms an extension westwards of the Clavering Road block of the main college building, and the principal dimensions are: length 60 feet; breadth, 43 feet; height from the lowest to the highest floor, 48 feet. Access is gained to the several floors of the engineering department from landings of the north-west staircase in the main building. The following description and woodcuts are taken from the college prospectus,—

The accommodation consists of three laboratories, a lecture-room, a drawing-class room, and other minor apartments. The laboratories, which comprise the engine-room, the machine-room, and the practical mechanics laboratory, are lined with white glazed brick, which greatly assists the lighting, and gives them a very bright and cheerful appearance.

The basement of the building (Fig. 1), which is only partially sunk below the ground level, and is amply lighted by large windows in the north and south fronts, will be occupied by boiler, engine, furnaces, and hydraulic appliances. A boiler is being specially provided for experimental purposes, and a steam supply is also obtained from the main boilers of the college, so that steam may be had to heat the building, to work the machines, and also to heat up the experimental engine, without interfering with any tests as to coal consumption which may be in progress. The boiler is designed for a working pressure of 200 lbs. per square inch, in order that engine tests may be made at high pressures. The pair of



BASEMENT PLAN. (FIG. 1.)



GROUND FLOOR PLAN. (FIG. 2.)

experimental engines shown on the plan have been constructed by Messrs. John Fowler and Co. They are designed to work quite independently, so that either may be used to drive the machines while the other is being experimented upon. The smaller engine, which has a cylinder of six inches diameter and twelve-inch stroke, is designed to work as a high-pressure engine with variable cut-off gear, and controlled by the governor or by hand at will. The larger engine, having a twelve-inch cylinder and twelve-inch stroke, will be arranged to work as a non-condensing, a surface-condensing, or a jet-condensing engine, with variable cut-off gear alterable by hand. A special form of coupling is being provided, by means of which the engines may be coupled with the cranks at any angle, and so coupled, the engine will be workable as a non-condensing, a surface-condensing, or a jet-condensing compound engine, using steam at any pressure up to 200 lbs. per square inch. The clearance volume at each end of each cylinder, the volume of the intermediate receiver, and the stroke of the air-pump can also be varied. Either cylinder may be worked jacketed or non-jacketed. All the necessary appliances will be provided for making complete tests of efficiency. It is further proposed to provide a gas-engine, to be used both for driving the machines while the steam-engine is being tested, and for illustrating the principles of that form of motor.

The furnace shown in the corner of the basement is arranged for annealing, case-hardening, and other processes. Besides this, a chamber, lined with firebrick and provided with a chimney, also lined, has been arranged so as to accommodate at any time, as required, a furnace fcr melting or other such purpose.

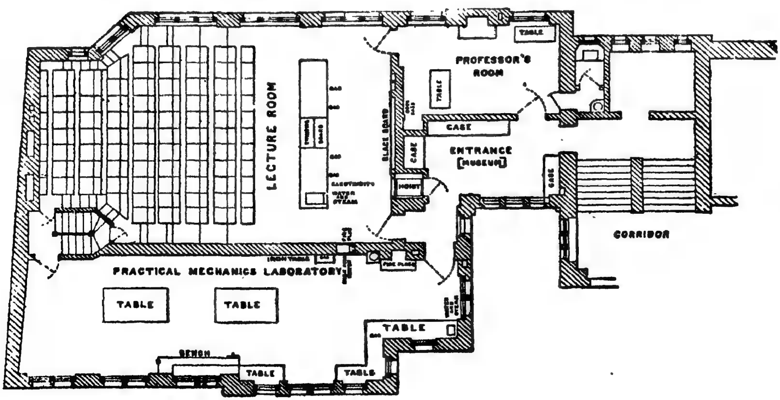
Provision is made for moulding and casting small articles, in order to familiarise students with the principles of these processes, and to enable experiments to be carried out on the properties of different alloys. A portable forge and a gas-blast forge, together with the necessary auxiliaries, also find a place in this room.

The floor of the basement is of concrete, and in it two drains have been laid, with openings at convenient places to facilitate the carrying out of experiments on the flow of water, on centrifugal pumps, and other questions in hydraulics, for which purpose a large water-supply has been provided in this part of the building.

A special arrangement has been made for the carrying out of delicate experiments on the elasticity of metals. Two square flues are formed in the gable, extending throughout its whole height. These open below into the recess shown on the basement plan, and on the longitudinal section, and are closed at the level of the drawing-class room ceiling by glass partitions, which admit sufficient light to render the specimens visible throughout their whole length. One of these flues has an opening at every twelve feet in its height; the other has openings only into the drawing-class room. At each of these openings a cast iron wall-box has been built into the wall, forming a strong and steady support for the cross pieces from which the specimens are suspended. In this way, wires or light rods up to fifty-five feet in length may be tested, the lower ends being accessible for applying the loadings and reading the extensions. In some of the experiments now being carried out, the loading is automatically applied at various rates, and the result recorded by an autographic apparatus designed by Professor Barr.

In the machine-room, which occupies the ground floor of the building (Fig. 2), the

LONGITUDINAL SECTION (FIG. 3.)



FIRST FLOOR PLAN. (FIG. 4.)

most noticeable piece of apparatus is a 100-ton testing machine, of Mr. J. H. Wicksteed's well-known single-lever vertical type, as made by Messrs. Joshua Buckton and Co. This machine is of exceptional dimensions, being probably the largest vertical testing machine ever constructed, and is specially adapted to the requirements of a scientific institution. The column of the machine, which is about sixteen feet in height, rests upon a massive foundation in the basement, and is brought up through the ground floor. The machine can take in specimens for tension or compression upwards of ten feet in length, and is therefore capable of testing many objects, such as tie-rods, struts, columns, &c., which, so far as we know, no vertical testing machine had previously been constructed to admit.

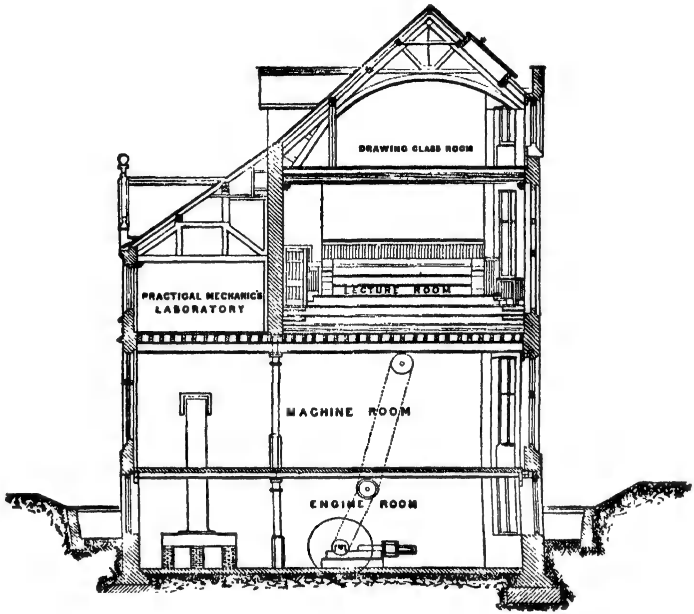
Another notable feature of the machine in the Yorkshire College laboratory, is that the displacer or pump is quite out of the way, and the specimen completely exposed to view on three sides, so that the progress of a test can be observed by a large number of persons at the same time.

The other appliances in this room are, as will be seen from the plan, a set of machine tools of the ordinary standard kinds. These will be used for the instruction of students in the principles of the action of cutting tools, and will be utilised also for the preparation of specimens for testing, and in the construction of tools and apparatus for use in the department.

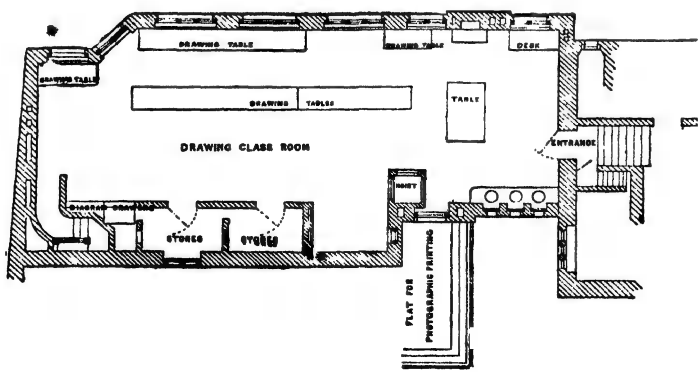
The ten-inch sliding, surfacing, and screw-cutting lathe, which has been supplied by Messrs. Shepherd, Hill, and Co., is on a sixteen-foot bed, and is a most complete and substantial tool. For most of the work to be carried on in the laboratory a much smaller tool would have been suitable. A lathe of this size has been chosen in order that the longest specimens which the testing machine will admit may be prepared in the laboratory, and further that practically valuable experiments may be made on different forms of cutting tools, cutting speeds, rates of feed, &c.

The other lathes are a seven-inch sliding, surfacing, and screw-cutting lathe, carrying its own counter-shaft, by Messrs. Greenwood and Batley; and a five and a half inch screw-cutting foot-lathe, specially made for the laboratory by Mr. F. E. Reed, of Worcester, Mass., U.S.A. The latter is fitted with American chucks and other auxiliaries. It is a good example of American practice, and its many niceties of construction render it admirably suited for the instrument-making and other kinds of light lathe work constantly requiring to be done in a mechanical laboratory. The planing machine has been specially designed and made by Messrs. Smith, Beacock, and Tannett. The table is actuated by a screw, driven directly by belting. The noise which necessarily accompanies the use of gearing is thus avoided—an important matter to attend to in the proximity of class-rooms.

The universal milling machine, and the milling cutter sharpening machine (Kreutzberger's), are from the works of Messrs. Greenwood and Batley. The former machine may be used for all classes of milling or circular cutting work, and is furnished with special appliances for gear-cutting and for making twist drills and reamers, and spiral, angular, or parallel cutters. The latter machine provides means of correctly grinding milling cutters, either of rectangular or curvilinear form, in such a manner that each tooth performs its due share of the work,—an essential point in the use of circular cutters.



TRANSVERSE SECTION. (FIG. 5.)



SECOND FLOOR PLAN. (FIG. 6.)

The radial drilling machine and the shaping machine are by Messrs. Napier, Fairbairn, Naylor, Macpherson, and Co. The drilling machine is an improved type of the machine originated by the late firm of P. Fairbairn and Co., and first exhibited at the London Exhibition of 1862. Amongst the special features of the shaping machine we may notice the following: The bed is carried down to the floor, thus giving support to the tables upon which the work is fixed, in whatever position they may happen to be; the connecting rod is in the centre of the ram; the feed motion travels with the head, so as to be always within easy reach of the attendant; the feed can be adjusted in any direction without stopping the machine. The six-inch slotting machine has been constructed by Messrs. Buckton and Co. The table is fitted with a very simple and convenient dividing arrangement.

On the first floor (Fig. 4), there are four rooms—the lecture-room, the practical mechanics laboratory, the professor's room, and a small entrance-room, which will serve as a museum in which to exhibit objects of special interest to students of engineering.

The practical mechanics laboratory, as its name indicates, is for the accommodation of appliances for the experimental study of the principles of mechanics and other branches of engineering science. Such subjects as the strength and stiffness of beams of various sections, the strength and stiffness of rods subjected to torsion, problems in inertia and momentum as affecting machines, friction, &c., are here investigated. Tables, fitted with gas, water, and steam for use in experiments relating to thermo-dynamics, &c., and tools for light work in wood and metal, and for soldering, brazing, and other processes, are also provided.

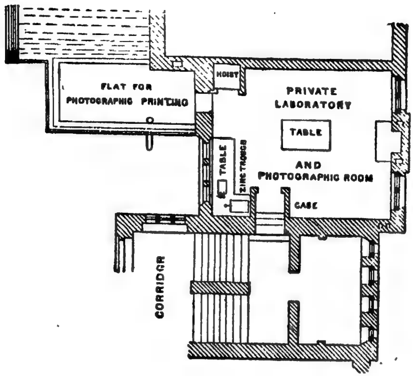
In the lecture-room, accommodation is provided for eighty students, but over 100 persons can be comfortably seated on the benches. The lighting of the room is particularly good, the windows being very large and facing the north. Here also, in common, we believe, with every lecture-room in the main college building, the light comes from the students' left. In the case of the engineering lecture-room, this is a specially important provision, as it is fitted with desks in the form of drawing-boards, so arranged that each student may attach a small sheet of paper to the desk before him, and copy accurately, by the aid of a T square and other instruments, any diagrams or drawings exhibited on the walls, or constructed on the blackboards, in illustration of a lecture. The desks will also be used for some parts of the work of the drawing classes in connection with a special provision of the lecture-table, which has been designed by Professor Barr, to facilitate the teaching of geometrical and mechanical drawing.

A very large blackboard occupies a part of the end wall space. It is hung on the system introduced by Professor James Thomson, and though it weighs some 220 lbs., it can be easily moved up and down by a touch of one finger applied at either end.

The ceiling of the lecture-room is about nineteen feet high, and as this height is not required for the professor's room, and the museum, a room has been arranged over these, to be used, when required, as a laboratory for special work, and as a photographic-room. (Figs. 3 and 5.) It is provided with appliances for carrying out the blue process and other branches of photography, and opens on to a flat having a southern exposure. (Fig. 7.)

The drawing-class room (Fig. 6) is supplied with an abundance of well-diffused light,

admitted through large windows in the north wall and in the north slope of the roof; and not only has the lighting of this and the other rooms during the day been amply provided



PRIVATE LABORATORY PLAN. (FIG. 7.)

for, but a system of electric lighting has been adopted, which enables evening students to carry on their work under equally favourable conditions in this important respect.

21. The Merchant Venturers' School, Bristol. (Plates 21 to 24 and the two Frontispieces).

The Society of Merchant Venturers is the only remaining trade guild in the city of Bristol, and, having regard to the success attending the old Trade and Mining School of Nelson Street, Bristol, conceived the idea of further developing its usefulness, and finally determined to erect new buildings for its accommodation and extension. For the realization of this idea an eligible site for the building was secured upon the ground formerly occupied by the old Bristol Grammar School, which was pulled down and the site cleared.

On the recommendation of Mr. Owen Roberts and Sir Frederick Bramwell, the author of the present volume was appointed architect for the work, and the new school has been designed and superintended by him, Messrs. Brock and Bruce being the contractors, and Mr. Withycombe acting as clerk of the works.

The sum expended has been not far short of 40,000*l.*, inclusive of the site. The building occupies the ground at the corner of Unity Street and Denmark Street, in the rear of College Green, and is four stories in height, exclusive of the extensive sub-basement let as wine-vaults. The foundations are 28 feet deep below Denmark Street, and for about half of the basement the sub-basement extends. The new schools cover an area of

26,000 feet superficial. They are designed in fourteenth century Gothic architecture, the exterior being faced with red bricks and specially selected Bath-stone dressings, and the roof is covered with green slating. The total height of the Denmark Street front from the footings upwards is 104 feet. The Unity Street front is for the most part 80 feet high. The view of the exterior is given in the Frontispiece.

Basement.—The rapid fall of the ground from College Green to Denmark Street makes it necessary to enter at the level of the mid-landing of the boys' stairs at the upper end. The main entrance is lower down in the rear of the Denmark Street front, and passing through the open porch and closed vestibule, the marble staircase is reached, which rises to the topmost floor, and is that chiefly used by the evening students. It is the principal staircase, and is constructed of white Massa Carrara marble, with marble mosaic landings and halls, the dividing wall being effectively arcaded.

On the left of the staircase a door opens to a landing and short stairs down to the anteroom, from which entrance is obtained to the gymnasium, the masons' and bricklayers' workshop, and the carpenter and joiners' shop well fitted with benches.

At the end of the staircase-passage is a lobby leading to the covered and open playgrounds, 126 feet long by 56 feet wide, at the east end of which is a boys' lavatory, and at the west end the boys' urinals and latrines, to be hereafter more particularly described. External steps at one end of this detached building lead to the asphalte flat over the heating and engine-room.

Returning to the principal staircase, we find glazed doors on the right of the foot of the staircase, which open to the basement corridor, on one side of which is the dining-room, 74 feet long by 22 wide, from which one-third has been cut off for an extra class-room, and on the other side is a range of nine separate cloak-rooms.

Between the west end of the dining-room and the kitchen and its offices, the boys' staircase rises to their entrance-door on the first landing. The order is, for the boys on arriving to descend to their respective cloak-rooms, entering by the corridor doors and leaving by the opposite doors into the covered playground, whence they return to the staircase leading to the great hall overhead, from which all the class-rooms are entered.

On the side of the boys' entrance is a gateway leading to the kitchen area steps, which give access to the kitchen offices and fuel stores, larder, gas-meter house, &c. On the south side of the kitchen are two store-rooms and three windows looking into the open area between it and the heating-chamber. From this area there are stone steps to the asphalte roof over and to the service side entrance-passage on ground floor.

Opposite the foot of the boys' staircase is the lift rising to the topmost floor, and beyond it is the ventilating-shaft in which the fan is placed, by which the extract current in the underground channel is actuated, into which the descending flues in the thickness of the walls from the various rooms debouch, and the down draught within them is maintained as more fully described in the chapters on heating and ventilation.

The dotted lines show the direction of the shafting, turned by bands from the gas-engine in the north-west corner of the heating-chamber.

There are two furnaces to the heating apparatus,—the pipes in circulation from which are half in connection with one furnace and half in connection with the other. There are twelve circulations in all. The pipes are $1\frac{3}{4}$ wrought-iron pipes laid on Bacon's system.

Ground floor.—Ascending the external steps from the area by the heating-chamber, we arrive at the passage leading on the right to the exit in Unity Street, and on the left to the asphalte flat over the vaulted heating-chamber, upon which a girls' cloak-room, lavatory, and W.C. have been constructed. Passing through the lobby we arrive at the caretaker's apartments and boys' staircase-landing, from which latter access is given to the arcaded corridor of the great hall, on the north side of which, looking into Unity Street, is a series of three class-rooms—25 by 22, and 14 feet high—with five rows of desks and benches, and master's table and platform, with blackboard behind. Over these three class-rooms are three more exactly the same size, and all of these have direct access to the hall without any intervening corridor, a gallery being formed within the open arcaded corridor. The absence of corridors in this building is in accord with the new principle of school planning expounded by the author in his lecture on secondary schools, delivered at the Society of Arts in 1880, and now forming the ninth chapter of this volume.

Each of the class-rooms is complete in itself; the heat is given by the coils of hot-water pipes in the slate-cased and dado-covered window-backs, and the heat may be turned on or off at the pleasure of the master. Also the fresh air may be regulated by a second handle. The extract ventilators are equally under control, and any master may have what temperature he pleases, or what changes of air he pleases, up to 60° of temperature, and up to four changes of air in the hour. The extract ventilators are all opposite the inlets and furthest from the source of heat, and the gratings of the extracts are in connection with the vertical descending shafts, which open into the underground channel, of carefully calculated sizes, the current in which is maintained by the fan in the up-cast shaft turned by the engine as already described. This process is repeated in the great hall and all the rooms in the building, with what success will be found described in the chapters on heating and ventilation.

Leaving the hall by the north-eastern door, we arrive at the mosaic floor of the landings and corridors of the Denmark Street end of the building. On the left is another class-room of the same size and shape as the others just described. In the north-eastern corner is the library and reception-room, which has an elegant pitch-pine, raised, moulded, and panelled ceiling, and high wall dados, surmounted with a rich Japanese wall decoration of embossed paper with gold ground.

There is a handsome bookcase with the beginnings of a good library. The waiting-room adjoins, and masters' common-room comes next, beyond which is the museum, to which the Clothworkers' Company have already contributed valuable collections in suitable cases. This room is handsomely fitted with pitch-pine panelled ceiling, Bath-stone piers and arches, and high panelled dado, and is about 44 feet square.

The passage leading *to* the museum and continued from the exit *from* the museum, surrounds an open area from which abundance of light is obtained to the corridors and staircase through delicately-tinted lead-glazing, and ventilation and light are given to the

masters' lavatory and W.C., opposite the entrance to which is the platform retiring-room, from the south-east corner of the great hall platform. Crossing the hall to the boys' stairs, we ascend to the

First Floor.—On the right of the boys' staircase-landing on this floor is a lobby giving access to the art drawing-school, 34 feet long by 23 feet wide, a charming room with a delicate-panelled ceiling in white plaster, temporarily used as a class-room, the building being already much too small for its purpose, and extension to College Green being projected.

On the left of the landing of stairs is the entrance to the gallery of the great hall, which gives access to the series of class-rooms next Unity Street. The gallery, it will be observed, not only comes to the front of the arcade, but returns across the west end of the hall. The view of the interior of this hall, given in the Frontispiece, is taken from below this end gallery front, and if the reader will turn to that sketch he will better understand what has been termed the *hall passage* system of school-planning, whereby the usual dark, ill-ventilated corridors are avoided, and the hall is brought into everyday use, and yet is available for special service by screening off the aisles with curtains, as is done at Miss Buss's North London Collegiate School for Girls, where the author first introduced this mode of planning into his own practice, as described in the ninth chapter. This hall has been much admired, and is certainly the most ornate and attractive feature in the building, with its glorious oak fan-traceried roof in the style of the fifteenth century. A range of five large windows—looking across the playground to the old mayor's chapel—are immediately opposite the five bays of the aisle arcade of Portland-stone piers and arches, with slate-shafted pillars in front, 22 feet high, to receive the brackets sustaining the hammer-beams carrying the vaults spreading over the four centred arches. The combination of waggon vaults with pendant fanwork springing from the ends of the hammer-beams is somewhat akin to that of Oxford Cathedral choir. The intention was to overcome the flatness of the ceiling, over which is the science department, and to recall at the same time recollections of the rich ceilings of St. Mary Redcliffe, Bristol Cathedral, and Bath Abbey, while at the same time to do honour to the worshipful Company at whose expense this noble pile of buildings has been erected, and whose members take a lively interest in its remarkable success.

The gallery has an ornamental railing, and the inside is covered with oak panelling. Oak panelling surrounds the hall 7 feet in height, which rises to 18 feet at the back of the platform. There is no organ, and various improvements were made in the execution of this design. A pitch-pine wood-block floor is laid over the concrete fireproof construction, sustained on iron girders, forming the roof of the covered playground and cloak-rooms, situated under this hall. Leaving the hall gallery by the principal staircase landing, we can enter the engineering drawing school, 59 feet long by 22 feet wide, by the door opposite, or by one on the left. A revolving shutter is arranged to divide this room into two when required. At the south-eastern end of the Denmark Street front is the engineering lecture-room, 32 feet long by 30 feet wide, fitted, as shown, with a professor's room or engineering diagram-room between it and the drawing-rooms. At this point is the lobby giving access to a cloak-room, lava-

tory, &c., from the mid-landing by a short flight of steps, on the side of the paper-store, over a part of the museum, having western windows overlooking the length of the play-ground.

Second floor.—Ascending to the second floor by the principal staircase, we enter the central glazed corridor between the physical and chemical departments, over which is a series of galleries to the different rooms through which it passes; this arrangement is exceedingly effective, and at the same time advantageous, and carries out the same principle of open corridors as far as practicable. The first room on the left is the *physical lecture-room*, 42 feet long by 27 feet wide, with its raised gallery and lecture-table, and connection with physical laboratory behind. The window sashes of the roof-lights are all fitted with black blinds for obscuring light at pleasure.

The *physical laboratory*, 32 feet long by 22 feet wide, is fitted up with double working-tables and wall-tables, stone benches, sinks; electric battery room and photometric room for gas analysis, &c.

The *metallurgical laboratory*, of the same size, is also fitted up with working-benches and tables and coke bunkers, sinks and closets, and a range of muffle and air furnaces, with flues therefrom, 30 feet in height. These flues and furnaces are sustained on projecting buttresses, carrying pointed arches, and the floor of the metallurgical room is fireproof; it is temporarily used as a plaster modelling room. There is a small demonstrator's room or office in each of these last rooms.

Crossing the topmost landing of the boys' stairs and the small gallery stairs, we come to the *combustion-room*, and the *balance-room* fitted as shown. The combustion-room has special light and ventilation by the roof. The stone tables have teak and glass hoods and descending flues. The extract air-flues appear in section in the walls, and by dotted lines in the floors of this plan. The *chemical laboratory*, with working benches for forty students, is a top and side-lighted room, 43 feet long by 28 feet wide. The demonstrator's working-bench and lecture-table is in the centre of the side opposite the windows; on either side of him is a draught-closet, and at the extreme end towards the west is a hooded stone table, and to the east the steam-drying and evaporating arrangement. The five working-tables are double, and for eight students each; two basins and three draught-closets to each table. The details are given to a large scale in Chapter VI. (Plate 39).

The *gas analysis room* is entered from both the chemical laboratory and from the landing of chief stairs. It is fitted with working-tables, draught-closet, sink and cabinets, and central table.

The *special operations' room* is next the *headmaster's room* in the north-east corner, and is fitted with working-benches, draught-closets, cabinets, sink, and a double working-table in the centre of the room. The passage from the headmaster's room leads straight into the *preparation-room*, which is situated between the large lecture-room and the small chemical class-room, and is fitted up with a double working-table, a sink and cabinet and two draught-closets, each in the thickness of the walls between them; the lecture-room on the one side, and the class-room on the other. These draught-closets are glazed both sides and ventilated, and that on the lecture-room side has its table fixed on wheels, so that it may be drawn in and out of the preparation-room.

The *chemical class-room* is fitted up with benches and with lecture-table, with trough and sink, and gas, &c., &c. The *chemical lecture-room* has its benches arranged on a gallery, under which are closets. The lecture-table is very complete, with drawers, gas and water supplies, and sinks, and fume-extract-shafts, &c., &c.; blackboards and diagram frames, with tackle for raising and lowering same, and for closing the windows and sky-lights with black blinds at pleasure.

All the principal rooms on this floor are lofty, some 17 feet high to the springing of the circular glazed top-lights, extending from end to end of same. The materials and workmanship throughout this building are of the best quality. The system of heating and ventilating is more particularly described in the eighth chapter. It may be interesting however, to give the details of the drainage, gas, and water supplies, which space has rendered it necessary to refrain from doing in other cases.

Drainage, &c.—The drains for the building are all constructed of Doulton's stoneware pipes, with the patent Stanford joint, and are jointed in addition with cement; and laid on a bed of concrete with a fall of two inches in every ten feet, and where the pipes pass through the building the entire trench is filled with concrete to the level of the surface soil.

The pipes, as far as practicable, are arranged to empty separately into "manholes," so as to facilitate repairs and inspection, or should stoppage occur it can be righted from these points without breaking pipes. A twelve-inch main syphon-trap, is fixed close to boundary wall in Unity Street, to prevent the back pressure of gas from main or public sewer, and inspection can be obtained from manhole formed at that point, into which all sewage and rain-water enters from all parts of school.

The soil and rain-water pipes are all fixed clear of the walls; the feet of the latter being made to discharge over open gulley traps, and the former carried up the full size to the highest point of building for ventilation. All lavatories and sinks are also arranged to discharge in the open, and are disconnected from drainage. Each manhole has also separate pipes for ventilation, and all are carried up to highest points of building. The soil and rain-water pipes have received two coats of "Angus Cameron's patent solution" internally, to prevent rust and corrosion, and are painted externally in the usual way.

The W.C.'s used within the building are Bolding's patent wash-outs, fitted with cisterns with syphons for flush and after-flush and chain and ring action, the fittings being either in pitch-pine or mahogany; each pan is trapped immediately underneath with a throw-out trap, and ventilation is provided to clear each. The lavatories are fitted with Finch's patent basins, with press-down action taps for supply, and trigger arrangement for waste; having rubbed slate tops, and, where abutting against walls, slate skirtings. Inspection caps to the traps to these fittings are also provided; and the pipes can be unchoked at these points should occasion require. The urinals are Jennings' lipped urinals, and are divided by enamelled slate divisions, and, where they abut against walls, similar slate is fixed. The flushing is by an ordinary stop-cock with copper spray pipes; but all floors are covered with lead seven pounds to the foot, neatly copper nailed, with turn up at sides to prevent absorption and for cleanliness.

The boys' external latrines and urinals are lined with glazed bricks, and are fitted with

automatic syphon action tanks; the latrines having continuous trough on Bowes, Scott, and Read's principle, with pitch-pine divisions and doors, with moveable oak seats. Each is well ventilated by means of apertures formed in end and side walls, also by louvres in the roof.

Fittings and students' benches.—The drainage attached to the internal fittings for chemical and other purposes, is constructed of acid-proof glazed stoneware pipes of varying sizes, and as they had to be laid in an ordinary floor, it was considered desirable to provide for possible leakage and damage to ceilings of rooms under. To prevent this, lead-lined channels are formed in the thickness of the floor, in which the pipes are laid, with overflow or tell-tale pipe fixed in same at convenient places, to direct attention in case any drains are out of repair.

It is also arranged for the waste pipes from the sinks and other fittings used by the students and masters, to pass first into an earthenware receiver, which empties into a funnel-shaped pipe, so that sediment, instead of passing into the drains, settles in the receivers, and is removed from time to time. Means of access have been provided for inspection and repairs to all parts of this drainage, and all parts are disconnected from main drainage, and made to discharge in the open.

Water supply.—The building is supplied with water from the company's mains in Unity Street, which is laid on with 1-inch stout lead pipe direct to the two tanks (each 6 feet by 6 feet by 5 feet), that are fixed in attic in roof over boys' staircase, where it terminates with a ball valve; a 1-inch stop-cock being fixed on main in a small cupboard close to exterior wall, immediately where pipe enters building, so as to shut all water off if necessary. From these tanks a ¾-inch pipe is laid to another tank, similar in size, that is fixed over main staircase, and also terminates with a ball valve.

The tanks over the boys' staircase supply all fittings in the north-west portion of building, and the tank over main staircase all on the south-east portion; separate branch pipes are taken from these tanks to supply the various fittings, and each has separate stop-cocks, so that one or any course of fittings can be placed under repair without interfering with other floors. Overflow and tell-tale pipes are arranged to each cistern and tank, so that prompt notice is brought to the eye, should anything go wrong with any tap. The supply to the chemical fittings, and fittings for other purposes, is taken from the tanks fixed over the boys' staircase for about one half the building, i.e. chemical laboratory, gas analysis room, special operation-room, and all sinks, boys' latrines and urinals in play-ground.

The tank over main staircase supplies the fittings to chemical and physical science lecture-room, physical science and metallurgical laboratories, chemical class-room, preparation-room, engineering, lecture, and drawing-rooms, also lavatories, &c., on second, first, and ground and basement floors. Stop-cocks are fixed so that the fittings can be repaired without emptying the tanks, and as they are at different levels, they are constantly full; the result being that there is always a reserve supply of water of some 4000 gallons. All pipes that are in roofs or other exposed places are laid in wood boxes filled with sawdust, and are so arranged that during vacation or in frosty weather they can be emptied to avoid damage.

Drinking-fountains are fixed in the playground, dining-room, and on first and second floors; but these are supplied direct from ascending mains from the company's service, so that they may not be affected by any neglect in cleaning the cisterns—being independent to them.

With reference to the fittings to students' work-benches, fume-closets, and lecture and masters' tables, they are arranged so that the taps are in suites of three: each master or student having the use of one set, i.e. one tap for drawing from, one for distillations, and one for small pump, and all are arranged with screw-nozzle, with nut and lining for hose to one size, so that any apparatus can be transposed and put to work in any room in the building. The total number of taps on chemical floor alone is about 200, and all are so arranged that, when repair is required, the pipe and taps can be easily removed, as connections by means of nut and linings, and long screws with lock and backnuts, are freely provided.

Gas to building and fittings.—The building is lighted by gas from the company's mains in Unity Street, and conducted thereto by means of a 3-inch pipe to a Glover's patent dry meter for 250 lights, which is fixed in recess formed in open area, with proper valve to shut all gas from building, and necessary syphon box to prevent condensed water from entering meter. This 3-inch pipe is continued from meter up to the level of second floor, and from that point a 2-inch pipe is fixed to ceiling line of same floor. Each floor has a separate service-pipe from this main, and a separate stop-cock for repairs if required. The great hall has also a separate service-pipe with a by-pass cock in addition, so that the gas can be lowered for lecturing if necessary, or prepared for the meeting of students prior to their assembling. The chemical, physical, science, and engineering lecture-rooms are also fitted up in similar manner, the two former being supplied with opaque blinds to the windows, so as to darken the rooms if necessary in the daytime. The class and other rooms generally are lighted by means of a two-light pendant, with tripod burners, and brackets, and two wall-brackets, one on each side of blackboard, the burners being Sugg's regulator burners; but the art and engineering schools are fitted with Sugg's Argand burners, and the light can be directed to any one given point if required.

The students' benches and masters' tables have a separate gas service, each student being provided with two points, and the masters eight points. The points for the master's lecture-table being arranged on the outer edge, thus leaving the top clear for apparatus. A separate meter and service is taken to the caretaker's apartments, which not only checks the consumption, but enables the gas to the entire building to be shut off during vacations. A separate meter and service is also provided for the gas-engine used for ventilating purposes, in driving the foul air extraction fan.

22. THE LONDON UNIVERSITY COLLEGE LABORATORIES AND ART SCHOOLS.[1]

This college, founded in 1826, incorporated in 1836, and chartered in 1869 for special purposes, was extended in 1871 for the Slade School; and in 1878, the foundation-stone of the north wing, last completed, was laid by Lord Granville. The new buildings,

[1] In the development of the plans and details of this building, the Author desires to acknowledge the assistance given to him by Mr. W. Proctor Baker, and Mr. Coomber the headmaster.

designed by Professor Lewis, and carried out by Messrs. Perry and Reed, provide improved and extended accommodation for the Slade School of Fine Art, and for zoology and comparative anatomy. The whole upper floor of the north wing has been devoted to physiology. On the ground floor and basement, chemistry is provided not only with space in the north wing itself, but also with a large annexed laboratory on the ground behind. Rooms set free in the centre of the building, by these new arrangements, have been so dealt with as to secure proper accommodation for the School of Engineering and a laboratory for practical botany. The physiological department consists of a set of eleven rooms, among them a lecture-room for 170 students, and a working-room for 100 students, with large windows to the north. Each worker is provided with gas supply for heat and light, water supply, and a locker or cupboard for his microscopes and instruments &c. The seats and tables are in parallel rows, facing northwards, each row being three feet above the row in front of it, in this way the light which it receives, nearly horizontally, cannot be intercepted. The other rooms are for various purposes. In the department of chemistry, the new analytical laboratory is a lofty hall (74 by 25), lighted from above. It contains working-benches for fifty students, all of whom are as far as possible prevented from communicating with or overlooking one another; and in this respect it is quite unique. In the middle of the laboratory are draught-tables and appliances for general use.

23. The Chemical Laboratory of Manchester Grammar School.
(*See Plate* 25.)

The best is here made of a very limited space. The arrangement of the rooms is singularly good, and the fittings are admirable. The architects are Messrs. Mills and Murgatroyd, and high praise is due to Mr. Jones the master, who made a study of every detail. The chemical science department occupies six rooms on the second floor. The gymnasium is in the centre of the school quadrangle, and the galleries form the gangway to the laboratory and lecture-room. The chemical laboratory is fitted up with operating benches for ninety students, with demonstrator's table at one end, and assistant's table at the other, and both at right angles to the benches they command. Draught-places are situated in two of the five windows. There is a special sulphuretted-hydrogen room at one end, with draught-place, and sink, and furnace. The ventilating-shaft, with central iron smoke-flue, is at hand, and ready for the withdrawal of all the vapours. At the other end of the laboratory are the balance-room and the class-room with lecturer's table, the apparatus-room and preparation-room adjoining the chemical lecture-room; between the lecture-room and the apparatus-room is a draught-closet, and there is a sink communicating with each.

24. Oldham School of Science and Art, with Physical and Chemical Laboratories.

The science and art buildings have been erected close to the original Lyceum, and externally are carried out in the same architectural design. In the class-rooms eighteen square feet is the area given to each student, and 15 ft. 6 in. is the height of rooms. Inlets for fresh air are opposite the foul-air extracts, arranged for use in varying propor-

tions required in summer and winter, and entirely under the control of the masters. The premises consist of the following departments :—

Ground floor.—No. 1 room, for machine drawing and geometry, 42 ft. 9 in. by 27 ft. 6 in.; No. 2 room, for machine drawing and geometry, 42 ft. 9 in. by 28 ft. 6 in.; No. 3 room, for machine drawing, 42 ft. 9 in. by 20 ft.; office and master's room, 20 ft. by 16 ft. 9 in.

First floor.—No. 4 room, for building construction, 42 ft. 9 in. by 27 ft. 6 in.; No. 5 room, for mathematics and theoretical and applied mechanics, 42 ft. 9 in. by 28 ft. 6 in.; No. 6 room, technological, 42 ft. 9 in. by 20 ft.; physical laboratory, 25 ft. by 20 ft.

Second floor.—No. 7, art room, 42 ft. 9 in. by 27 ft. 6 in.; No. 8, chemical lecture-room, 42 ft. 9 in. by 28 ft. 6 in.; and chemical laboratory, 32 ft. by 25 ft.

I now proceed to describe some of the rooms more in detail.

No. 1 room, ground floor.—Machine drawing and geometry classes.—This room will accommodate sixty-five students at one time, each having a desk-space of 2 ft. 8 in. long. The desks are arranged in two rows of five each, one row having six students on each desk, and the other seven. The desks are 2 ft. 2 in. wide, with horizontal tops, stained and varnished, with ink-pots in same, 5 ft. apart, the specified distance for Government examinations. Each student is provided on the desk with an upright gas standard, which can be adjusted at pleasure to any angle to obviate casting shadows. Each standard has a reflecting tin cone and tin tube to carry away products of combustion ; the tube rises to a height of 5 ft. 7 in. above floor, thus being beyond the breathing level, and the cones radiate sufficient heat to warm the rooms, thus avoiding the necessity for a large amount of heating apparatus. The forms are 11 in. wide, and the full length of the desks. The desks and forms are all fixed on ornamental iron standards, which have been cast at Messrs. Platt's works. There are two blackboard frames fixed to walls, each having two blackboards, 6 ft. by 4 ft., made to slide, and divided into 3-inch squares to correspond with students' notebooks for sketches in reduced proportions. Contiguous to the blackboards, on the right hand, a cupboard is provided for masters, with shelves for storing drawings, &c. The blackboards are provided with all necessary accessories, such as chalk-boxes, compass rests, duster hooks, &c. Lights are fixed over the blackboards at a considerable distance from the floor, and reflectors throw light on to the lower boards. These lights are supplied with gas, independent of the gas standards, which have a main stop-tap in each room ; on the same side of the room there is a rail, 5 feet 9 inches from floor, for hanging drawings of double-elephant size. Four feet from floor is a shelf for manipulating models, to be seen by all the students, while there is another shelf, 7 feet 8 inches from floor, for storing models. Open curved hooks for T squares are pitched between hat and coat hooks, fixed 6 feet from the floor; above racks for students' drawing-boards, are placed round the room, and have hinged lids to protect the drawings from the rain-droppings falling from the coats and hats which hang above. A notice-board is at the entrance, and a water-tap, with fixed basin is in the room.

No. 2 room, ground floor.—Geometry and machine-drawing classes.—This room will accommodate a similar number of students to No. 1 room, and is in all respects fitted up in a corresponding manner.

No. 3 room, ground floor.—Machine-drawing class.—This room is fitted up with eight desks, each being 16 feet long, and accommodating six students, a total of forty-eight.

Porters' room, ground floor.—A small room is provided for the use of porters.

Office, ground floor.—A master's room, with office, is provided near main entrance. This room is well fitted for the purpose intended, having desks, cupboards, with pigeon-holes, for properly classifying all the papers of the different departments. There is a pay-door in vestibule for students when paying fees, &c.

No. 4 room, first floor.—Building construction room.—This room is fitted up for sixty-five students, and is in all respects similar to No. 1 room.

No. 5 room, first floor.—Mathematical and theoretical and applied mechanics classes.—This room is fitted up with the same number and dimensions of desks as Nos. 1, 2, and 4 rooms, but accommodation is provided for eighty-five students, the space required for each student in the absence of drawing-boards being 2 feet; the lighting is by means of two starlights of twenty-five lights each.

No. 6 room, first floor.—Technological cotton manufacture class.—This room is fitted with desks for sixty-four students, and is lit with two starlights of fifteen lights each.

Physical laboratory, first floor.—This room, used for lectures in acoustics, light, heat and steam, is fitted for sixty-six students. The seats are arranged in the centre of the room, and have sloped writing-benches, 9 inches wide, for students to make notes during lectures. There is a blackboard for master's sketches; at the front of the board is a lecture-desk, and on each side of the board are large cupboards for stores of physical apparatus. Students' benches, 2 feet wide, for experiments, are fixed round the walls; over these, 2 feet from benches, are cupboards, with glazed fronts, 20 inches by 12 inches deep (carried on brackets from the walls), for apparatus. The benches have air gas-burners, retort-stands, &c. Sink and water are also provided.

No. 7 room, second floor.—Art classes.—This room is fitted with six desks, 22 feet long, each desk accommodating nine students, or a total of fifty-four. The desks are sloping, and have racks and stands at the back of the same for supporting examples. A space is reserved at the end of the room for large models. The side walls are fitted with drawing-board racks, and with shelves for storing casts. This room has a Mansard roof, the windows being in the sloping sides. In the evening the room is lighted with two large starlights.

No. 8 room, second floor.—Chemical lecture-room.—This room is fitted for sixty-five students, with desks, &c., as No. 1 room.

No. 9 room, second floor.—Chemical students' experiment note-room.—This is fitted with desks, &c., as No. 1 room. Seven large cupboards are provided in which to store chemical apparatus.

Chemical laboratory, second floor (Plate 26).—This room is over the physical laboratory, and is fitted up in a most complete manner, being considered one of the best in the whole country. Fifty-six students are accommodated; a class of twenty-eight can simultaneously experiment. The benches have tops of teak wood, 2 feet 3 inches in breadth, spaced into 4-foot lengths, called writing-benches, and 3 feet high from the floor. Each has two shelves, with twenty-five re-agent bottles, the acids having

enamelled labels, the remainder varnished labels. There is an open space from the table-top to the bottom shelf where gas is laid on, a nozzle being provided for fixing a flexible tube with air gas-burner. Every two students have water-tap and sink between them, with provision for using same as pneumatic trough; a residue drawer lined with lead for filter papers, &c. Each place has a swing seat of convenient height, and there is a drawer with desk-top for students to use when making notes of chemical re-actions, having ink-bottle, recess for papers, &c.; also an apparatus drawer, with divisions for iron and brass materials. Under the table-top are two shelves for glass apparatus, covered in by pitch-pine slide fronts, set back to allow of students sitting to their work. Under the sinks are cupboards for retort-stands and iron apparatus. One important addition to the working-table is a closet behind the sink, high enough to admit retort-stands, and flasks for gases and sulphuretted-hydrogen. There is a 6-inch earthenware pipe from each of these chambers, giving a powerful down draught emptying into a 9-inch main, which is carried into a cast iron flue, ascending the main chimney shaft. A manhole in the shaft gives access to a large gas bracket in the iron flue; the gas flame aids the aspiration of the chambers in the summer, when it is unnecessary to work the furnace of the heating apparatus. The chambers are joined together in open groups of two and four, have an air feed at the top, and at the bottom are lined with lead, having fused joints. Wooden stoppers for air-hole and exhaust-pipe are provided. Coal gas is inserted and has the tap outside, so that the flame may be regulated without opening the glazed doors. There is also a top gaslight to each bench 6 feet from floor. All waste, drain, flue and water-pipes are easily accessible to workmen by means of a false floor. Fresh air is supplied by direct vertical inlets. The upper part of the laboratory is cleared from fumes by special extractors into the ventilating-shaft, the gas-closets aspirating noxious vapours. The benches are divided into four groups; two centre blocks, each with eight working-places; the others range down two sides of the room. Windows in a Mansard roof supply a good side-light to the students. There is a combustion-chamber, and two sets of shelves for chemical and stock re-agents, a large ventilated lead-lined sink, with glazed top and slide door. There are two cupboards in the laboratory, one for chemical stores, and the other a master's cupboard, containing substances for analysis. A small screened apartment is taken off the laboratory for quantitative analysis and chemical balance, fitted with shelves, necessary apparatus, and standard re-agents.

The fittings in all the rooms, but more particularly in the laboratories, have been most carefully worked out by Mr. Phythian. The fittings in the chemical rooms are executed in pitch-pine, varnished, the whole of the other fittings being in St. John's pine, stained and varnished.

The total number of students for whom seats are provided is 651, but this does not represent the full capacity of the school, as 1500 students can be accommodated. It now remains only to add to this description of the works that they have been carried out at a cost of from 9000*l.* to 10,000*l.* The entire expense has been defrayed by S. R. Platt, Esq., J.P., and his brothers. Messrs. Woodhouse and Potts are the architects.

25. THE MASON COLLEGE, BIRMINGHAM. (*See Plates 27 to 29.*)

This college, founded by Sir Josiah Mason twelve years ago, was originally designed for teaching only chemistry, physics, mathematics, and biology. It was afterwards determined to add to the above sciences, physiology, geology and mineralogy, mining and engineering, and also to form an art side, including classics, English, French and German; considerable modifications of the original plans were obviously necessitated; therefore, in judging them, these facts must be borne in mind. The site also was very circumscribed and surrounded by buildings, so that the principal lighting had to be derived from internal quadrangles, and great height was necessary, the blocks varying from three and four to five stories in height. The architect is Mr. Cossins, who visited the foreign examples and studied the matter well, working *con amore* with his patriotic client, who entered into every detail with remarkable ability and zeal, and the result has been a noble building of which Birmingham may be proud.

Plans of the ground, first, and second floors are given. There is a lofty, well-lighted basement, the ceiling of which is five feet above the ground level. In the back part of this story, under the physics laboratory (not a good place, however, being too near the physics laboratory) are numerous machines belonging to the engineering department, all of which are driven by an engine of twenty-horse power in the annexe; this laboratory was originally intended for a chemical store.

There is also an extensive mezzanine providing some good class-rooms, &c. The Bradburn's hydraulic passenger-lift, intended to be fixed near the central staircase, has not been carried out.

The general arrangement of the building is as follows:—

Opposite the main entrance on the *ground floor* (Plate 27) is the central corridor, crossing the quadrangle and forming east and west courts, on the right side of which corridor is the main staircase, and on the other side the cloak-rooms and lavatories, &c., which are repeated on each floor. Right and left of the entrance-vestibule, in the rear of the front block, are corridors leading respectively to the east and west staircases; on the east side of entrance are the porters' rooms, the Natural History Society's room, and professors' common room; on the west side inquiry and clerks' office, secretary's office, and board-room.

Passing down the central corridor we arrive at the large laboratory for physics on the left of the northern block, and the library and reading-room on the right, with anterooms; by a passage to east staircase, the women's reading and cloak-rooms are gained. A similar passage on the west side gives access to the private physics laboratory, the private rooms of the professors of physics and engineering, and the president's room. Beyond the apparatus-lobby, north of the physics laboratory, is a large drawing-office, from which a staircase descends to the machinery-room, steam-engine, &c. In the rear yard a large room has lately been provided as a students' common-room.

On the first floor (Plate 28) are three lecture-rooms reached by the central staircase and corridor: chemistry in front, and physics, biology and mathematics in the rear; to each of these there is a preparation-room, and chemistry has a large collection-room

besides, physics an apparatus-room, and zoology a museum and work-room on one side of its preparation-room, and a demonstration-room and biological professor's room on the other side. On the south-eastern corner are two rooms for languages.

On the second floor (Plate 29), at the southern end of the central corridor, is the examination-hall, and at the northern end the two chemical laboratories for quantitative and qualitative students. North-west of the latter laboratory is the balance-room, beyond which is the demonstration-room, and gas and water analysis. From the eastern corridor access is gained to the store-room, the combustion-room, the library; and beyond the east staircase is the chemistry professor's private laboratory. The rooms forming the geological department are on the western side of the examination-hall; at the southern end of the central corridor is a staircase to the museum over the examination-hall.

The system of heating and ventilation adopted at Mason's College is as follows:—

The laboratories, lecture-theatres, staircase, and corridors are warmed with hot air from a chamber under the basement, 90 feet long by 8 feet wide and 6 feet high, containing an enormous coil of 4-inch water-pipes heated by a tubular boiler, 23 feet long and 4 feet in diameter. Under the coil-chamber is another chamber or channel the same length and width, but only 18 inches high; this is a cold-air chamber arched over with a half-brick arch, with 3 by 2½ aperture spaces left in every course of the arch at 9 inches' distance from each other, for the passage of fresh air to the coil-chamber; these openings have been reduced in number and adjusted as required. The cold-air chamber is supplied with fresh air by large downcast flues, as nearly equidistant as the plan admitted; after passing between the heated pipes the air finds its way into nearly every part of the building by means of flues built in the thickness of the walls which leave the top of the heating-chamber. So long as the flues are vertical they answer very well, but it is found that the horizontal flues do not conduct the heated air in sufficient quantities to distant rooms.

The large annexe at the back of the building is warmed by pipes in the usual way, the smaller rooms have open fires. All rooms have flues connected with warm-air chamber, and though the heat derived therefrom is small, the ventilation is said to be improved thereby. The jacket of the great chimney forms the extract upcast shaft, with which all the rooms are connected with horizontal and vertical flues; but the draught-closet flues, although connected with the exhaust flue, have also gas jets to create a draught at first. The system is not one to be imitated.

26. THE NEW CHEMICAL LABORATORIES, UNIVERSITY COLLEGE, LIVERPOOL.

(*See Plate* 30.)

The new chemical laboratories in connection with University College, Liverpool, opened by the Earl of Derby, the President, mark a new and important step in advance, being the first instalment of building undertaken by the college on a scale of academic completeness.

Dr. Campbell Brown, who has held the chair of chemistry for nearly twenty years, has worked out with unwearied patience all the details required to give

completeness to his department of study, and has been suffered to consult with and to instruct the architect employed, the result of which has been to give to Liverpool one of the most complete and amply fitted chemical laboratories in the kingdom, so far as it has gone, for there yet remain to be built the two great laboratories, together 60 feet by 60 feet, divided in the middle.

The work was entrusted to Mr. Alfred Waterhouse, R.A., whose previous experience in the erection of similar laboratories for Owen's College, Manchester, the Yorkshire College, Leeds, and the Central Institution of the City and Guilds Institute for the Advancement of Technical Education at Kensington, has given him unrivalled mastery among English architects of this particular branch of building. It is not, therefore, surprising that this moderate-sized example of an English university chemical laboratory is replete with all the latest improvements in ventilation, fittings, and general planning, at an expenditure of some 16,000*l.*, exclusive of the cost of the site.

As already observed, the entire design will not be completed until the erection of the two laboratories to be situated side by side after the manner of those at Owen's College, and extending from the north end of the present building in Dover Street. The buildings are erected in the Romanesque style, faced with grey stock brick, with terra-cotta and Ruabon brick, and may be regarded as striking the keynote for the contemplated college of the future.

Illustrative plans are given herewith taken at the level of the two theatres, viz. a ground-floor plan and a second-floor plan, and the titles of the rooms on the intermediate plan are also indicated. The two theatres are novel things in their way, and worthy of imitation as examples of one of the most convenient forms of planning for hearing, speaking, seeing, and simultaneous working.

Ground Floor, Fig. 1.—The *practical* theatre or class-room laboratory is especially arranged for a large number of students to follow by actual experiment on their own part the demonstrations given by the lecturer, whose table is placed in the middle of one side of the room, a few feet away from the back wall and between the two entrances. The students' working-benches are fifty-two in number, and are arranged in six concentric rows rising one above the other. These rows form segments of circles described from the lecturer's position as a centre. By this arrangement the acquisition of a knowledge of elementary practical chemistry is greatly facilitated and rendered more thorough. The more advanced teaching is conducted in various special laboratories throughout the building and will be further provided for when the large laboratories are built. The containing-wall of the room opposite the lecturer is itself polygonal. The theatre measures 48 feet 6 inches in width, and 42 feet 6 inches in depth, from the centre of the face of the back wall to opposite outer wall face. The height of the room is 19 feet 6 inches. There are lofty windows in the polygonal wall and also at both sides of the room.

The working-benches of the students are of pitch-pine, and are fixed on the steps of the gallery, the rise of which is an elliptical curve; they are arranged in pairs, each pair having a small fume-chamber and porcelain sink in common, but provided with separate cupboards, drains, gas nozzles, &c. The drawers and cupboards stop short of the front of

the benches to allow of enclosed re-agent shelves, about 6 inches deep, for the use of the students in the next row, so as to avoid the necessity for re-agent racks on the benches themselves. Each student has 4 feet of bench length, the dual bench being about 8 feet long. The lecture-table is 20 feet long by 3 feet wide, fitted with every necessary appliance, and on the wall behind are blackboards, fume-chambers, cupboards, and shelving. Large fume-closets are provided for the students' use, in addition to the small ones on the benches. The theatre is lighted by three Bower gas-lights. Close to the preparation-room and practical theatre is the sulphuretted-hydrogen room, 26 feet 6 inches by 14 feet, with special ventilation and niches for the supply of students, with automatic check apparatus to prevent waste in use.

The remainder of the ground floor is occupied by two rooms for storage, a lavatory, students' conveniences, heating apparatus, coal-cellar, gas-engine, dynamo and fan apparatus, condensed steam or distilled water cistern, &c., &c.

It may here be stated that the building generally is supplied by fresh air, heated by low pressure hot-water piping, arranged in long underground channels; the warm air rises through vertical flues in the thickness of the walls to the various rooms. The current is accelerated by a fan driven by a gas-engine; the fresh air is made to pass through a water-spray for cleansing and moistening the atmosphere on its way to feed the fan.

The extraction of foul air is both by special gas jets and by means of a furnace at the base of the great shaft. The chemical fumes from the various fume-chambers and other appliances, as well as the naturally vitiated air of the rooms, are drawn downwards through special extraction flues to the base of the upcast ventilating-shaft, the draught of which is accelerated by the spare heat from the adjacent smoke-flue, aided by an open furnace which can be lit at pleasure; there is no internal iron smoke-flue. The extract-ventilators in rooms are fixed at the upper part of the room near ceiling, and in some cases also near the floor, and are fitted with outside small American roller-blinds, so that the draught may be regulated as desired.

The evaporating-closets are very effective, with glazed back and divisions of thin glass, the back glass stopping short of the cover by about two inches, over which the fumes flow and escape by the descending flues in the walls in connection with the extraction system.

Hot water for drawing off at various points in the building is provided by a separate service. A steam-boiler is also provided, and steam laid on for heating students' air ovens, for evaporation and distillation, and to such places as are likely to require its use in experiments. The heating apparatus is arranged to give a temperature of 60° when the external temperature is 25°, and was fixed by Haden.

Second floor, Fig. 2—Ascending the principal staircase to the second floor, we find the corridors arranged as on the floors below the two southern ones leading to either side of the lecture-theatre, and including between them the internal open area for light, and the indispensable preparation-room for the service of the lecture-theatre.

This theatre is exactly the same size as the practical theatre under it, and has three lofty windows at each side, but there are no windows in the polygonal wall, skylights being substituted; it can be darkened at pleasure, and is provided with the Bower gas-lights.

The seats are arranged in the same concentric form, radiating from the lecturer as a centre, and accommodation is provided for 212 students, with sufficient room to use the book-boards for writing and taking notes of lectures (260 could be seated in the ordinary way). The lecture-table is 25 feet long by 3 feet wide and is provided with gas, steam, hot and cold water, with oxygen, hydrogen, and sulphuretted-hydrogen supplies. Separate taps on the table communicate with an air-blast and a vacuum, while wires bring a current of electricity when required. Two flues opening on the table convey fumes and offensive gases to the main upcast shaft. The table is also provided with a pneumatic trough, a mercury trough, and other conveniences; behind the table are cupboards for re-agents, blackboards, and diagram racks.

Overhead is a cove in the ceiling for the purpose of deflecting outwards to the audience the sound of the lecturer's voice. In the wall behind the lecturer is a large fume-chamber, the glass doors of which open to the lecture-room in front and to the preparation-room behind; a powerful draught on each side communicates with the main ventilation-shaft. The base of this fume-chamber is a granite table, which is set on rails, and can on occasion be moved forward to the lecture-table or backward into the preparation-room, which also communicates directly with the theatre by a door in the rear of the lecture-table.

I have been thus particular in the description of this lecture-table, because it is a sample well worked out of the many aids now available to save the time of the lecturer and of the student, and to render the experimental teaching more thorough and complete than could be the case without them.

An anteroom for lecturers and a large room for apparatus and diagrams adjoin the lecture-theatre. The north corridor of this floor communicates with a private laboratory for a few of the most advanced students, with the professor's room adjoining —a small class-room, 22 feet by 16 feet 2 inches—and on the other side a chemical museum, 28 feet by 24 feet. This organic portion of the museum is being arranged on an effective educational plan, the fundamental hydro-carbons being placed on the lowest shelf, and each shelf above containing the derivatives in order of derivation, so that the homologous series is in horizontal lines, and the analogous series in perpendicular lines. Thus the specimens graduate in complexity from the lowest shelf upwards, showing a tabular arrangement at a glance.

The apparatus for lectures is kept ready for use in the apparatus and diagram-room in the order required for the various lectures, and, including the diagrams, is properly classified for progressive teaching.

A staircase leads to two small rooms in the tower containing spectroscopes and microscopes, and to the large water-cistern; it also gives access to a lead flat. This, in addition to a second stair as an alternative route, leads to a range of storage-rooms in the roof, and a room for the preparation of diagrams.

A lift travels from the basement to this storage floor. If we descend the principal staircase to the first-floor landing, we reach a corridor corresponding with those of the other floors. At the far end of this corridor is the eastern entrance from the college grounds. South of the corridor are rooms for gas analysis, a room arranged for operations in sealed tubes and other special operations in organic chemistry, a dark room

for photography, photometry, &c., and a ladies' cloak-room and lavatory. The corridor running north leads on the east to the organic laboratory, 28 feet 6 inches by 24 feet, which will be temporarily used as a quantitative laboratory.

The walls are lined with cream and dark gold-coloured glazed bricks, and the room is supplied with hot and cold water, steam, hot-air baths, fume-chambers, evaporating niches, and chambers for organic combustions, and other conveniences. West of the corridor are three rooms, each 22 feet by 16 feet 3 inches, viz. a room for water analysis and distillations requiring steam, a balance-room also used as a reading and writing-room, and a gas-furnace room intended ultimately to communicate with the future large quantitative laboratory. The future openings are at present bricked up. This corridor also contains a range of lockers for the use of students.

27. The Huddersfield Dyeing and Weaving School and Mechanics Institute.

(*See Plate* 31.)

This is a handsome structure designed by the late Mr. Edward Hughes, a local architect, in the geometrical Gothic style. It is well-planned and takes the form of three sides of a quadrangle, the space between the wings being appropriated for the weaving shed, which is well stocked with large and small looms. It is indifferently heated and not ventilated at all, a circumstance particularly noticeable in the laboratory for dyeing, which is admirably fitted up under the supervision of Professor Jarmain. Unfortunately the vapours produced by the steam-heated dye-vats, with their moveable porcelain pots, hang about the room till condensed by the cold wall surface. It is a question whether it was wise to place the dyeing and chemical laboratories on the ground floor of a three-storied building, but when it is needful to do it, too great pains cannot be taken with the ventilation. Gas jets are used for the extraction of the foul air from the draught-closets. The fittings generally present few novelties; the most interesting and valuable are those of the dyeing school.

On the ground floor (Fig. 1) the space occupied by the weaving-sheds is 92 feet 6 inches by 41 feet 6 inches, roof-lighted, and well adapted for the purposes to which it is applied. The weaving lecture-room is in the north wing, and is 22 feet by 39 feet 6 inches. The physical science and chemical lecture-room, 22 feet by 30 feet 6 inches, is at the other end of the same wing; between them is a class-room and the preparation-room.

The secretary's room and council-room are on the left of the chief entrance from Queen Street south; on the other side is a class-room. In the south wing is the chemical laboratory, 22 feet by 36 feet 6 inches; an instrument and balance-room coming between it and the dyeing-room, 22 feet by 46 feet 6 inches. A small room is set apart for a steam-boiler at the end of the south wing, and in a similar position in the north wing a corresponding room is fitted with a gas-engine.

On the first floor (Fig. 2) are six small class-rooms, a reading-room and library, and mechanical class-room.

On the second floor (Fig. 3), besides three small class-rooms, there is a large art school, 60 feet by 28 feet, art master's room, and cast-drawing room. Extending across the main portion of the front of the building is the large lecture-room, 68 feet by 36 feet wide, with wide platform and organ, and a gallery at the opposite end.

28. St. Thomas's Hospital Medical School. (*Plate* 31.)

The medical schools of our hospitals are an important part of those beneficial institutions, and I therefore give a plan of a comparatively modern example, so well carried out by Henry Currey, Esq., the architect, under the direction of Dr. Bristowe.

The peculiarity of this design is that, owing to the irregularity and restrictions of the site, it is a single-story building, almost entirely lit from the roof. The underground passage from the hospital (shown in dotted lines) leads straight to the lift communicating with the mortuaries, of which there are two, one public, the other private, situated between a waiting-room and the post-mortem room, out of which is the prosector's room and morbid anatomy chamber on one side, and the large dissecting-room for twenty tables on the other or north side. Out of the east side of the large dissecting-room is the lecturer's room, the demonstrator's and porter's rooms, and door to yard. Adjoining it, on the north side, is the anatomy theatre, recently enlarged, with steps down to the lecturer and up to the back seats. East of the theatre are the curator's rooms.

On the other side of the central corridor, which runs north and south, is the chemical theatre with chemical laboratory adjoining. The private laboratory comes next, and the balance and furnace-rooms. On the other side of the intervening lavatories is the physiological department. The fittings are shown throughout.

Beyond the cross corridor, at the north end, is the museum on the east side of the central corridor; on the west side is the medical theatre and materia medica and chemical museum.

This school has the credit of considerable convenience; indeed, the unusual extent of land available has given an opportunity for arranging the school on one floor, to the great convenience of all concerned.

29. Owen's College, Manchester.

The chemical laboratory at this College, executed from the designs of Mr. Waterhouse, in accordance with the arrangements prescribed by Professor Roscoe, is one of the earliest and best of English examples. The chief features of the building are two large laboratories, each 70 feet by 30 feet, and 29 feet high. One laboratory is devoted to the first year or qualitative students, in which there are working-places for sixty students, in six blocks of ten places each. The other is ranged for forty advanced or quantitative students, and contains ten blocks of four places each. Parallel with the quantitative

laboratory, and divided therefrom by a corridor, is a series of rooms, viz. two balance-rooms, organic analysis and gas analysis rooms, a library and organic chemistry lecture-rooms. At one end of the two laboratories is the staircase, on one side of which is the chemical store and re-agent room, and on the other the professor's private room—over which are Professor Roscoe's private room, overlooking both laboratories, and his private laboratory and balance-room. In the basement is a third large laboratory for fifty medical and for evening students, a metallurgical laboratory containing furnaces, a store-room, class-room, lavatory and cloak-room, spectroscopic-room, photographic-room, dark-room for photometry, boiler-house, and three preparation-rooms. The large theatre for 380 students is detached from the working laboratories, and has its lecturer's laboratory or preparation-room, draught-closets, sinks, &c., adjoining in the rear, and communicating directly with the space behind the lecturer's table.

The ventilation of the laboratory is both general and special. The general ventilation is effected by a perforated boarded ceiling running the whole length of both laboratories, and conveying the vitiated air by a large air-trunk to the shaft, within which rises the smoke-flue of the furnace. The supply of fresh air is obtained from a high level by a fresh-air shaft, down which the air passes, being drawn over the hot-air pipes by the aspiration of the chimney, and passing into the laboratories through gratings placed in the walls. The special ventilation is also worked by the main shaft, and is divided between the evaporation niches in the walls and the sulphuretted-hydrogen closets. Each of the niches is provided with an upright glazed earthenware pipe, 4 inches in diameter, running into a horizontal pipe of the same material, 12 inches in diameter, communicating with the draught of the main chimney. The large niches at the end of the laboratory aspirate 100 cubic feet of air per minute, each of the smaller ones in side walls 12 cubic feet per minute. The sulphuretted-hydrogen closets in each working-bench are joined together in groups of two and four, and placed in connection with a 7-inch or a $4\frac{1}{2}$-inch glazed earthenware pipe, communicating with a horizontal flue shown in section, running between the fire-proof arching and the floor, and passing into the chimney shaft. Each closet in No. 1 laboratory aspirates at the rate of 5 cubic feet per minute, whilst those in laboratory No. 2 aspirate 20 cubic feet per minute, those at the farthest end of the laboratory differing but slightly from those nearest the chimney.

30. THE MEDICAL SCHOOL OWEN'S COLLEGE. (*Plate* 32.)

The completion of this range of buildings gives me the opportunity, through the kindness of the Dean and Mr. Waterhouse, of giving an interesting example of the various requirements of a medical science school. The technical character of the work done in medical schools must be obvious to all who think of it; skilful manipulating fingers are as necessary as pure science to growth in knowledge. The laboratory must go hand in hand with the lecture and the class-room.

This building consists of ground and first floors with a mezzanine floor between over the smaller rooms of the ground floor, in so far as the first portion of the building extended; the

second portion is a four-story building. It may be convenient to describe the earlier building first, floor by floor.

Ground floor (Fig. 1)—Entering through the porch, a janitor's room and a professor's common-room open from the vestibule leading to the central-hall staircase, on the opposite side of which are the professor's lavatory, and a professor's private room. Right and left of the entrance-hall stairs are the medical and the anatomical theatre ; the professors' entrances being through their respective rooms, and the students' entrances being from the first and second landings of the stairs respectively. Under the raised seats of the two theatres are students' hat and cloak-room, professor's lavatory, and room for stores.

The seats and desks of the anatomical theatre are concentric, the curve radiating to a centre just in front of the lecturer's table, which is a revolving one. The medical theatre has straight seats and backs; both have the usual slate and diagram frames, &c., &c. On one side of the lobby from professor's private room to the anatomical theatre is a lift, by which subjects are raised from the mortuary and other rooms in the basement of this part of the building, reached by an inclined roadway. On the left side of the hall is the entrance to the museum, fitted with glazed cases filled with valuable specimens. Off the passage leading to the attached new building is the library, fitted with tables and book-cases. The levels of the floors of the attached building being different, we descend a few steps to the students' reading-room, and to the Medical Society's reading-room, the three rooms communicating with each other. On the other side of the staircase is the museum of materia medica, fitted with wall-benches, tables, and glazed cases, the curator's room overlooking same.

Mezzanine floor (Fig. 2).—We now reach the mezzanine floor, passing the students' entrances to the anatomical and medical theatres, as we mount the central staircase of the first building; on the left side of the landing is the students' common-room and a H.M.C. or scullery, next which is the entrance to the intermediate or first gallery of the museum, at the other end of which is a door to a staircase leading to the second gallery and to the professor of anatomy's private-room. At the foot of this staircase is also an entrance to a museum work-room, fitted with tables, sinks, glazed cases, and a lathe ; returning to the central staircase, we next enter the anatomical work-room, which is fitted with tables, sink, cases, &c., and has communication with the lift. A passage on the side of this room leads to the still-room.

There is no connection on this floor between the first and second building, but the plans show that it is chiefly occupied by the upper part of the larger rooms below; the first landing of the staircase giving entrance to a museum of hygiene, to be found in the gallery of the museum of materia medica, and the next landing admitting to the laboratory of the materia medica and the lift. The laboratory is fitted up as shown with central double working-table, wall-benches, draught-closet, sink, and glazed cases.

First-floor plan (Fig. 3).—Ascending the central staircase of the first building, we arrive at the great dissecting-room, fitted up with eighteen operating tables, wall-benches, sinks, and a series of anatomical preparations preserved in spirits and ranged along the entrance-wall. At the end of this room are two preparation-rooms, through one of which communication is obtained with the lift.

The lighting is not only by windows, but by skylights the whole length of the room, which when opened help to become extractors, by a range of hot-water pipes which is carried from end to end at the foot of the sloping lights in the open roof. A store-room and a bone-room are entered from the dissecting-room, through which we reach the central stairs again and find access to the second gallery of the museum, a demonstrator's room and small bone-room with stairs to rooms over these, and the students' lavatory.

The first door on the left of the passage to the second building is the laboratory of histology in the physiological department, seven working-tables are situated at right angles to the platform; there are also wall-benches and sinks, and glazed cases; the space is much too limited. From the mid-landing of stairs, entrance is made to the private laboratory of materia medica, fitted up with its benches, cases, tables and sinks, and draught-closet. A lift also opens to this landing.

Off the next landing are the laboratory of surgical pathology and special room off same, the private laboratory of pathology, and the students' laboratory of pathology; the fittings of each of which are shown, and it is regretted that the space should be so limited. The sizes of the rooms are not to be imitated, except to show how to make the best use of limited resources.

Second-floor plan.—Ascending the staircase to the first landing we arrive at the practical physiological room for students, fitted-up very similarly to the private laboratory beneath it. On the top-landing entrance is made to the optical laboratory of surgical pathology, with its dark-room with sink off same, its benches on wall-brackets, and glass cases; adjoining is a balance-room.

On the other side of the landing is the gas analysis room, professor's private room, and the laboratory for physiological chemistry and lecture-room, fitted with double working-benches, with draught closets and sinks, wall-benches, sinks and glass-cases, and a well arranged working lecture-table.

The macerating-room is in a separate building, the smells being passed through a furnace and lofty chimney.

31. THE NEW PHYSIOLOGICAL LABORATORY, OXFORD. (*See Plate* 33.)

Dr. Burdon Sanderson has worked out a very complete physiological laboratory for Oxford, and plans of each floor are given.

It is not the first time that Dr. Sanderson has been so engaged. University College, London, is also indebted to him for designing the fitting-up of the physiological laboratory at that institution; and the example I am thus enabled to give is not only the latest in point of time, but in point of merit, since it is the outcome of the ripened experience of a remarkable man. My acknowledgments are due to Dr. Sanderson, not only for allowing me to see his personal sketches, but for his great kindness in giving me a written description of his intentions. I need hardly say that I have not ventured to make much variation from his text in the account which is here given.

A physiological laboratory is intended partly for practical instruction, partly for

experimental investigation. As the subject comprises three branches of study, namely, 1. That of the mechanism of the animal body; 2. That of the chemical processes which are carried on in it, and 3. Physiological anatomy and histology,—it is necessary to provide for each of these subjects.

In the Oxford laboratory the rooms devoted to these divisions of the science are entirely distinct, and in each subject the two purposes of research and instruction are separately provided for.

The laboratory contains thirteen working-rooms, in addition to a lecture-room, a private-room for the professor, and one for each of his three co-adjutors, a store-room, a workshop, four dwelling-rooms for the caretaker and mechanician, a book-room, and a lavatory.

The basement, which extends under part only of this building, comprises a well-lighted workshop, two working-rooms, and the caretaker's kitchen. The workshop is fitted with lathe and other appliances for working in metals, a two-horse power gas-engine, a dynamo (for supplying electric light), a centrifugal machine, and other apparatus. One of the working rooms in the basement is specially constructed for experiments in which it is essential that the temperature should be subject to very slight variation. It is provided with double walls and vaulted roof, and is carefully ventilated by a draught-flue fitted with extractors, which work satisfactorily.

Ground floor (Fig. 1).—Access is given to the rooms on the ground floor by a long corridor, which extends from the principal entrance to the door of a large room called the practical physiology-room, at the north-east corner of the building.

Of this room, which is devoted to practical instruction in elementary physiological physics, the principal feature is that the two long fixed tables which face the windows are provided with horizontal shafting, driven by Thirlmere water-motors, from which rotatory motion can be distributed to any of the moveable working-tables, so that, if necessary, a dozen pieces of apparatus can be driven at the same time. It is also provided with clocks, which are connected electrically with the working-tables, so as to mark seconds when required, and other appliances for facilitating combined observations.

To the left of the practical physiology room is the research-room; here are also a Thirlmere motor, and various large instruments for investigations relating to mechanisms of respiration and circulation. There are also in this room, as in the practical physics room, glass cupboards filled with an endless variety of instruments. Into this research-room, the professor's private-room and a room for books and writing materials open.

From the practical physiological room, we enter first the galvanometer room, and a room called on the plan the dark-room; in this former (which is exclusively devoted to experiments in animal electricity) the most prominent object is a brick-built column surmounted by a stone slab, on which stands a Thomson's galvanometer. In all directions insulated wires suspended from the ceiling are seen, which connect various pieces of apparatus. The so-called dark-room is intended for experiments chiefly relating to physiology of vision, for which the exclusion of light is essential, and it contains various pieces of optical apparatus.

Returning by the corridor towards the entrance, we come to a room devoted to investigations in which it is necessary to use mercury in considerable quantities; it

contains a large mercurial air-pump, apparatus for the measurement of gases, and for the analysis of gaseous mixtures. The floor of this room is of concrete, and is so inclined that if mercury is spilt, in consequence of the accidental breaking of glass apparatus in which it is contained, it can be recovered without loss.

Access to the *first floor* (Fig. 2) is obtained by a wide stone staircase which rises from the north end of the corridor. From the head of the staircase a very short corridor or passage leads to the chemical laboratory. In the opposite direction a door leads directly into the histological working-room; from it a door opens into the private-room of the demonstrator of histology, which faces eastwards, and into a room devoted to instruction in elementary physiological chemistry.

The chemical laboratory is fitted for the accommodation of twelve workers, it is spacious and lofty, has abundant window ventilation, but is not ventilated artificially. It contains two large working-tables, each 16 feet long, with cupboard and drawers for each worker; the sinks, wastes, and water-supply apparatus are in the middle. At the north end of the room is a stone shelf surmounted by a hood for combustions, with draught-flues furnished with extractors. On the west side there are large fume-chambers furnished with extractors, the sashes and frames of these chambers are of wood and glass, the floors of stone, water and gas are supplied in such a way that the supply of both can be controlled by taps outside of the chambers. Against the south wall of this laboratory is a table provided with arrangements for filtering under pressure, and between the east windows stone tables for ovens and water-baths.

Adjoining the chemical laboratory on its north side, is a small balance-room, which also serves the purpose of a private-room for the gentleman who has charge of the department of physiological chemistry.

The lecture-room occupies the south end of the first floor. The lecture-seats look northwards, and rise from the level of the floor with a sufficient inclination. The lecture-table is of brickwork, which rises from the foundation of the building, its top is of teak, and it is provided with water and gas supply, which are so arranged as to be completely under the control of the lecturer.

A Duboscq's lantern, for projection with a Siemens' electric lamp, occupies a table facing the lecturer, and is so placed as to project on a 10-foot screen which is fixed behind the lecturer. The lecturer's platform communicates directly with the chemical laboratory by a hatch or window; it contains a fume-cupboard and various apparatus for demonstration.

The histological room is fitted with tables for twenty-six students, these are in two rows, parallel to each other and face the very spacious windows. The tables farthest from the windows are so much higher than the others that their tops are above the heads of those who sit in front of them, so that all equally have the advantage of horizontal light; each worker is provided with a cupboard for the reception of his microscope and other instruments or appliances.

The room for practical instruction in elementary chemical physiology is furnished with tables for twelve students, so arranged that each student may face the demonstrator; each table has water supply and gas supply, but is arranged with much greater simplicity

than those of the chemical laboratory. At the east end of the building are two rooms devoted to photography, viz., a working-room and developing-room; the arrangements being such that either electric light or sun light may be used.

32. THE CHEMICAL LABORATORY, CAMBRIDGE UNIVERSITY. (*See Plate* 34.)

This is an interesting and instructive example of the requirements of the day, brought down to the latest date, the building being in course of erection.

The original instructions of the Senate to the Syndicate were to obtain plans and estimates for a geological museum and a chemical laboratory in the southern portion of the old Botanic garden site, enlarged by the acquisition of the Persi almshouses; care being taken that the geological museum, which is to form the Sedgwick Memorial, be a distinct and conspicuous feature in the building.

The deliberations of the Syndicate brought them to the conclusion that they could best carry out their instructions by beginning with the chemical laboratory.

Professors Liveing and Dewar had previously collected copies of the plans of most of the newly-erected laboratories of Europe; and Professor Liveing and Mr. Trotter had made a special tour in order to inspect those of Strasburg, Munich, Leipsic, and Aix-la-Chapelle; while Professor Dewar had visited that of Geneva and some others, so that all the materials needed for framing the instructions to the architect were ready to hand. This is the only way to secure a really good building; nothing is so fallacious as the system too often adopted of consulting the professor about the fittings only, after the building has been erected; in some cases the fittings also have been completed before the appointment of the professors.

In the present instance the general plan of the building, and the arrangement of the fittings, was well considered before the architect was appointed, by the professors who would have to teach in it; and Mr. J. J. Stevenson, the architect, has therefore been able to produce a building singularly well arranged for the purposes it is to serve, and worthy of the thoughtful consideration of the student.

The interference of ancient overlooking lights has caused inequality in the elevations, which has been turned to account by the architect to produce picturesque effects; the central building being flanked by comparatively low wings, that on the right being the general laboratory, that on the left the large lecture-hall and caretaker's house.

Illustrations are given of the ground and first-floor plans, but there are a basement story and two intermediate or mezzanine stories in the centre of the main block, before and behind the main staircase. There are also spacious attics in the lofty roofs.

The basement is sunk about 5 feet below the level of the street, and, owing to the slope of the surface, rather less below the ground at the back; it extends under the whole building, and in it are provided (beneath the lecture-room) an unpacking-room, easily accessible from the street by an inclined plane, and two store-rooms adjoining (beneath the main building, accessible by the principal staircase), a large room for a metallurgical laboratory and a furnace-room adjoining it, a room for organic analysis, and one for such

operations as the heating of substances under pressure, a large room, 41 feet by 33 feet, to contain a steam-engine, dynamo-electric machine, and other machinery, also a lavatory and cloak-room. In the rear of the machine-room, but accessible independently from the yard, is the boiler-room, capable of holding boilers to supply steam for heating the whole building, as well as for the steam-engine.

Underneath the northern wing are two rooms which are to be fitted with uninflammable materials, where such operations as the distillation of ether and other easily ignited substances can be carried on, a small laboratory where a special class of students can work, a store-room, a lavatory and a small chamber with windows all round it, where experiments with such substances as chlorine or bromine can be carried on with as little inconvenience to the operator as possible. These rooms are all accessible by a staircase which is in direct communication with the principal students' laboratory above, and also with the courtyard.

The porters' lodge occupies the corner next Free School Lane; it has kitchen, parlour, and scullery on the ground floor, and three bedrooms above. A window in it commands one of the chief entrances to the buildings on that side.

On the ground floor the large lecture-room is 40 feet square, and will seat 204 persons on benches rising towards the back, so that all can see the lecture-table; it is 30 feet high to the ceiling, and if at a future time more accommodation should be required, a gallery can be constructed to hold 70 persons in addition. This room is accessible by two entrances. An archway carried through the building underneath the raised part of the floor of the lecture-room gives access from the street, both to the lecture-room and to the yard behind. Adjoining the lecture-room and communicating with it behind the lecture-table, are the preparation-room and the specimen-room, which are also provided with independent access to the yard and to the store-rooms below, and to a small private laboratory and balance-room above. These rooms also serve for the use of two smaller lecture-rooms which adjoin them on the east side. The lecture-room will be connected for the purpose of ventilation with the general ventilating-shaft in the middle of the building, and will be provided with a separate draught-chamber for lecture experiments.

The principal entrance to the main building is from Pembroke Street. A flight of fourteen steps from the pavement reaches the entrance-hall on the level of the ground floor, whence access is had to the two smaller lecture-rooms, each 29 feet by 24 feet, and to the principal range of students' laboratories. The general arrangement of these laboratories is similar to that of the new laboratories in the University of Strasburg, having a central room for large operations between two larger rooms fitted with the usual benches, and appropriated to beginners and more advanced students respectively. The draught-closets will be placed in the windows as in the laboratory at Munich, each with its own flue and draught, hastened by a gas jet, an arrangement which is found to work well at Munich, and better than the more elaborate contrivances adopted in some other places. The ventilation of the rooms will be provided by means of a ventilating-shaft, carried to a height of 100 feet, heated in the winter by the fires of the steam-boilers, or when they are not in use, by a separate fire. In one corner of the large laboratory, a small chamber similar to that in the basement, ventilated by windows

all round, will serve for operations with chlorine. The balance-room opens through a lobby into the central room and into the advanced students' laboratory. A stink-closet for sulphuretted-hydrogen is placed next the ventilating-shaft and ventilated thereby. Lifts place the laboratories in communication with the store-rooms below. In addition to the access from Pembroke Street, a staircase at the north end gives access to the large laboratory from the courtyard. The floors are of wood, which on the whole have been found to be most satisfactory. The drains are formed of iron troughs lined with asphalte, carried between the joists beneath the level of the floor, covered by moveable boards and accessible at all points.

The principal staircase is in the centre of the building, lighted by a skylight. Ascending from the ground floor, in the mezzanine between the first and second floors, are two rooms, one over the entrance-hall, which is intended as a private room for a professor, and another over the balance-room intended for gas analysis.

On the first floor are two rooms of the same dimensions as the small lecture-rooms on the ground floor, of which one may be used as a professor's laboratory, and the other as a class-room. These rooms also communicate with the private laboratory above the preparation-room. On this floor is also a second range of students' laboratories, consisting of two laboratories and a balance-room, of the same dimensions as the rooms below, and another private room for a professor. The largest of the rooms on the ground floor is not carried higher; but in the attic over it is a large space which may be utilized for some purposes, and the central part of the roof is flat, so that on it such experiments as are best carried out in the open air can be conducted.

In the mezzanine between the second floor and the attic above it, are two rooms similar to those beneath, of which one may serve as a library and calculating-room, and the other is left unappropriated.

In the attic there is a considerable space, of which part may be appropriated to chambers for the assistants, and the rest will be available for making and storing diagrams for spectroscopic observations, and for other purposes which do not require any special appropriations.

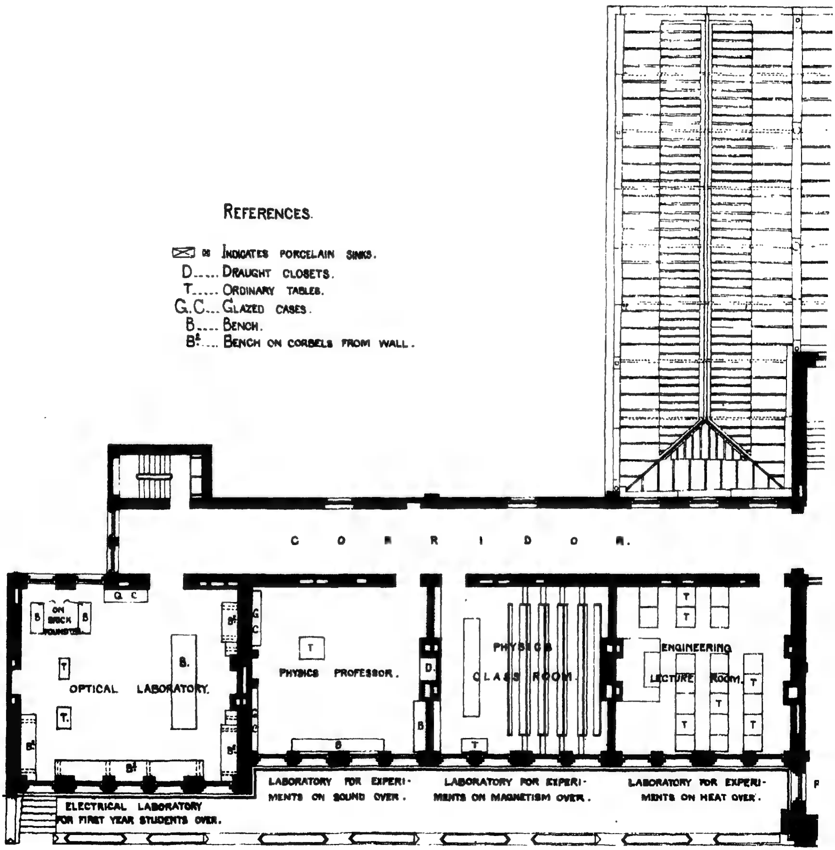
It is calculated that the students' laboratories will accommodate 175 students working at one time, and if further extension should be required hereafter, it could be attained by putting another floor above the northern one-storied wing, which would provide room for about seventy-five more.

A careful study of the plans of the chief Continental and English laboratories recently erected, has led to the adoption of every appliance which has proved successful.

The architecture has been throughout subordinated to the necessities and convenience of the building. The first requirements of the building are ample light and thorough ventilation, for which the large windows, divided by stone mullions, are very suitable; this form of window has also the advantage that it permits the irregular arrangement of the floors necessitated by the plan, without breaking up the regularity of the front. To allow the light to reach well into the rooms, the windows are kept square at the top and close to the ceiling, except in the lecture-hall, where round-arched windows (which, however, give ample light) seem to be demanded by the architecture.

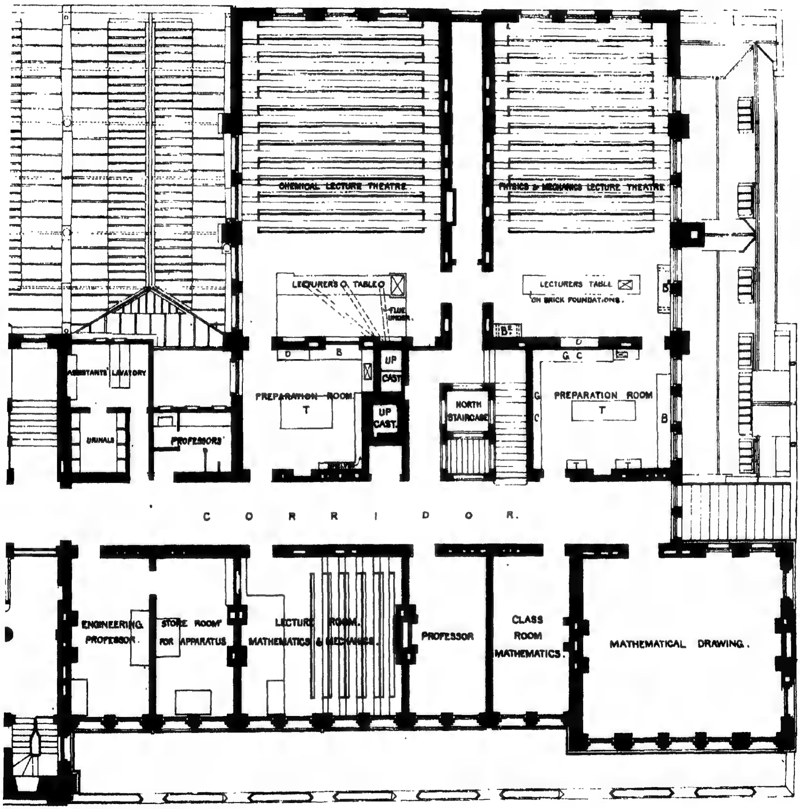
The estimated cost of the building, including fittings and machinery, amounts to about 31,000*l.* It may be mentioned that the total expenditure is not at all excessive in comparison with the sums expended upon similar buildings elsewhere. The Chemical Laboratory at Strasburg, though designed for a smaller number of students, cost 35,000*l.*; that at Munich, exclusive of the lecture-room, 30,000*l.*; and that at Aix-la-Chapelle 75,000*l.*; while at so small an institution as the new college at Dundee the authorities have thought it necessary to expend 15,000*l.* on the laboratory.

THE CENTRAL INS



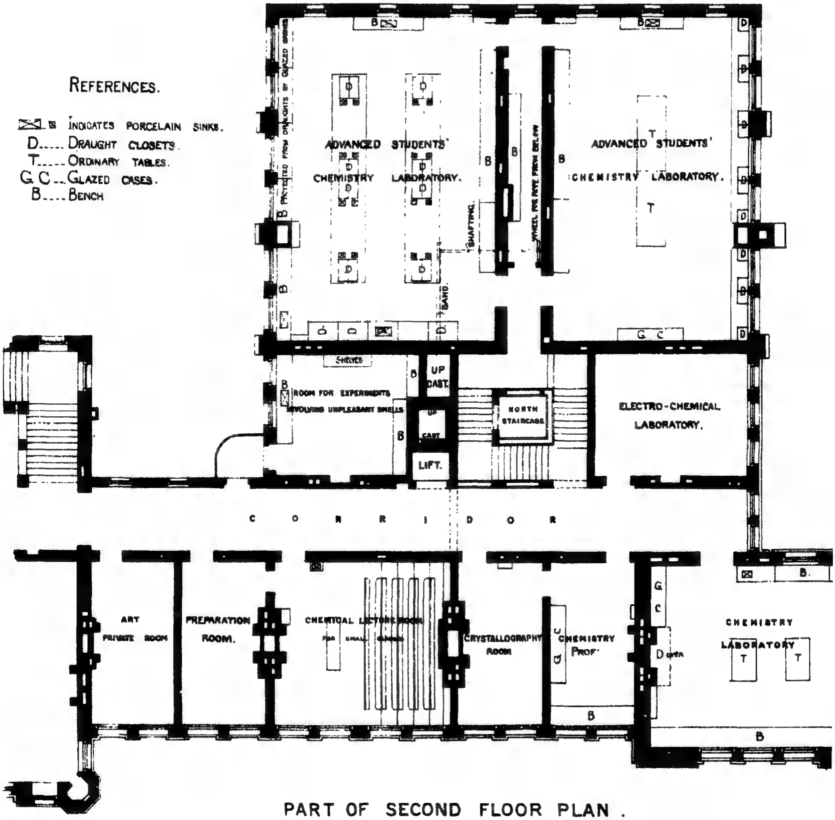
GF

'OUTH KENSINGTON.



PLAN.

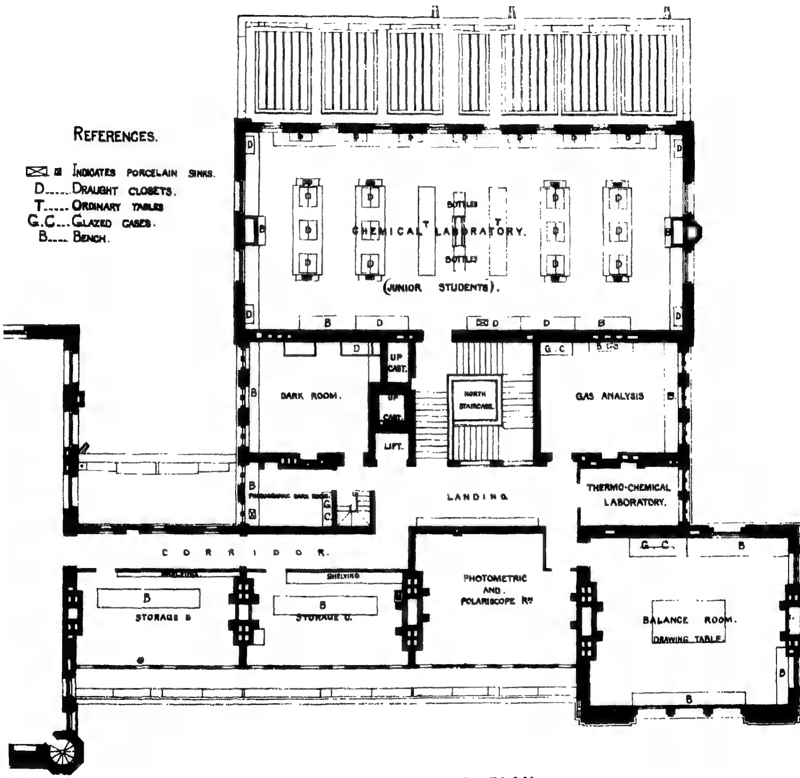
A. WATERHOUSE, R.A. ARCHITECT.



PART OF SECOND FLOOR PLAN.

FIG. I.

)UTH KENSINGTON.

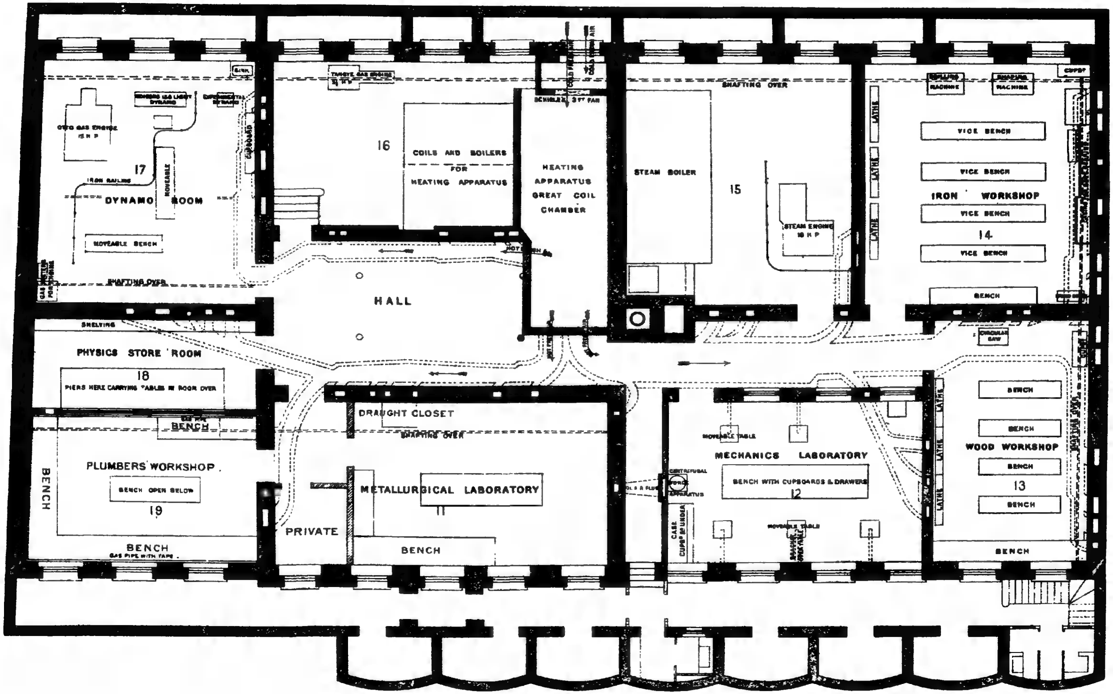


PART OF THIRD FLOOR PLAN

FIG. 2.

A. WATERHOUSE, R.A. ARCHITECT.

FINSBURY TECHNICAL COLLEGE.

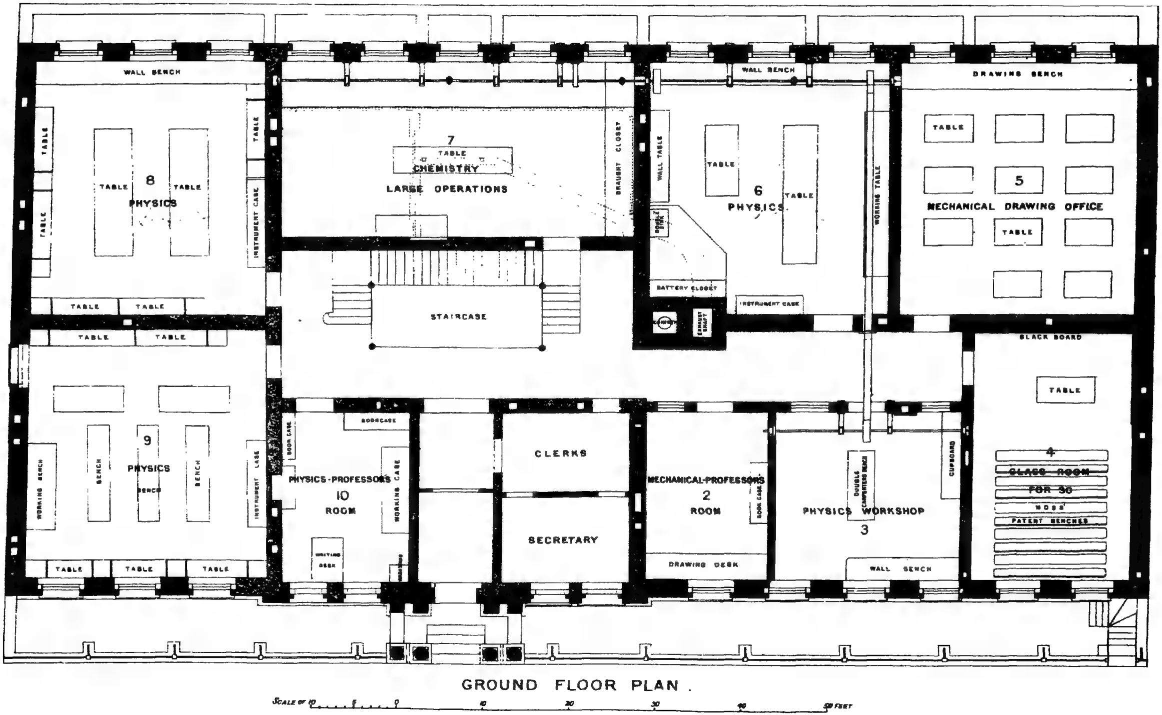


BASEMENT FLOOR PLAN.

SCALE OF 10 5 0 10 20 30 40 50 FEET

E. N. CLIFTON, ARCHITEC

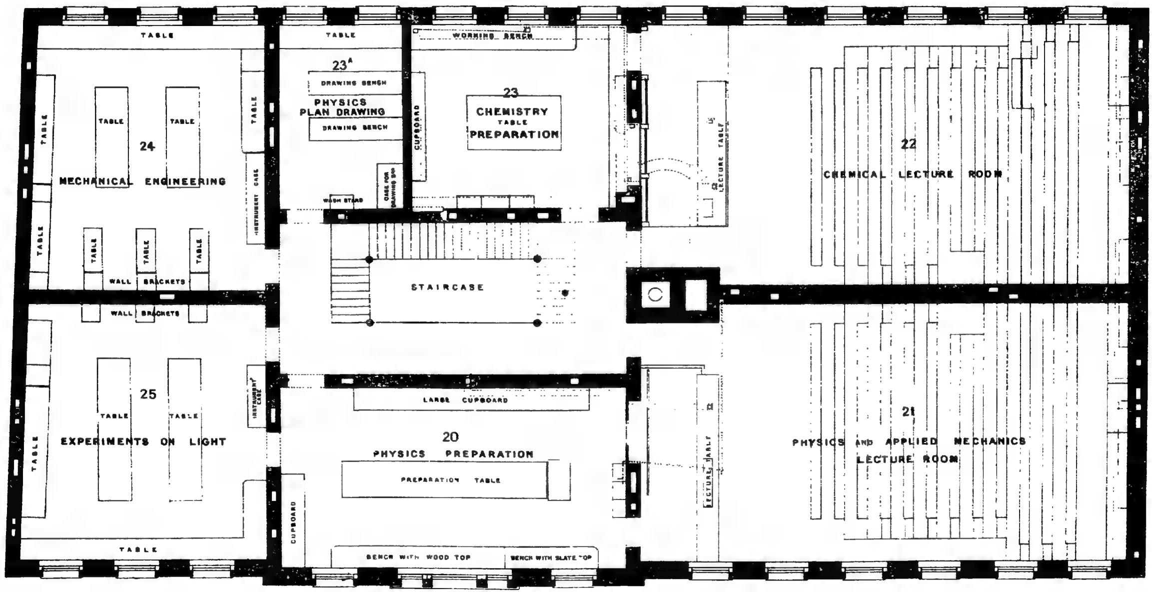
FINSBURY TECHNICAL COLLEGE.



GROUND FLOOR PLAN.

E. N. CLIFTON, ARCHITECT.

FINSBURY TECHNICAL COLLEGE.



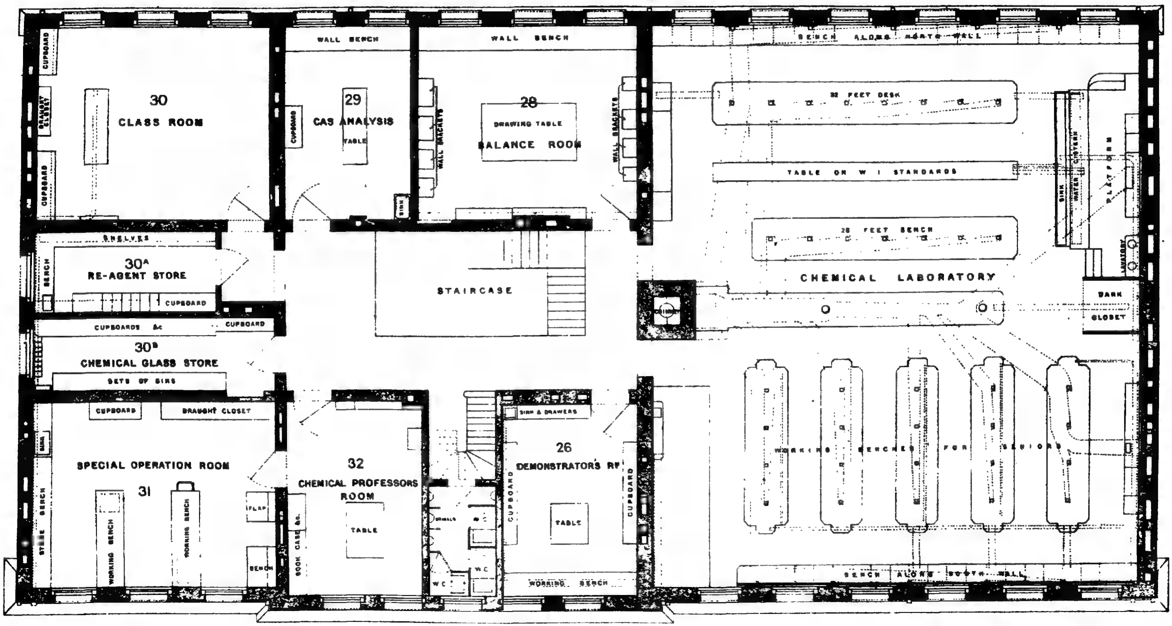
FIRST FLOOR PLAN.

Scale of 10 5 0 10 20 30 40 50 Feet

E. N. CLIFTON, ARCHITECT.

PLATE 17.

FINSBURY TECHNICAL COLLEGE.

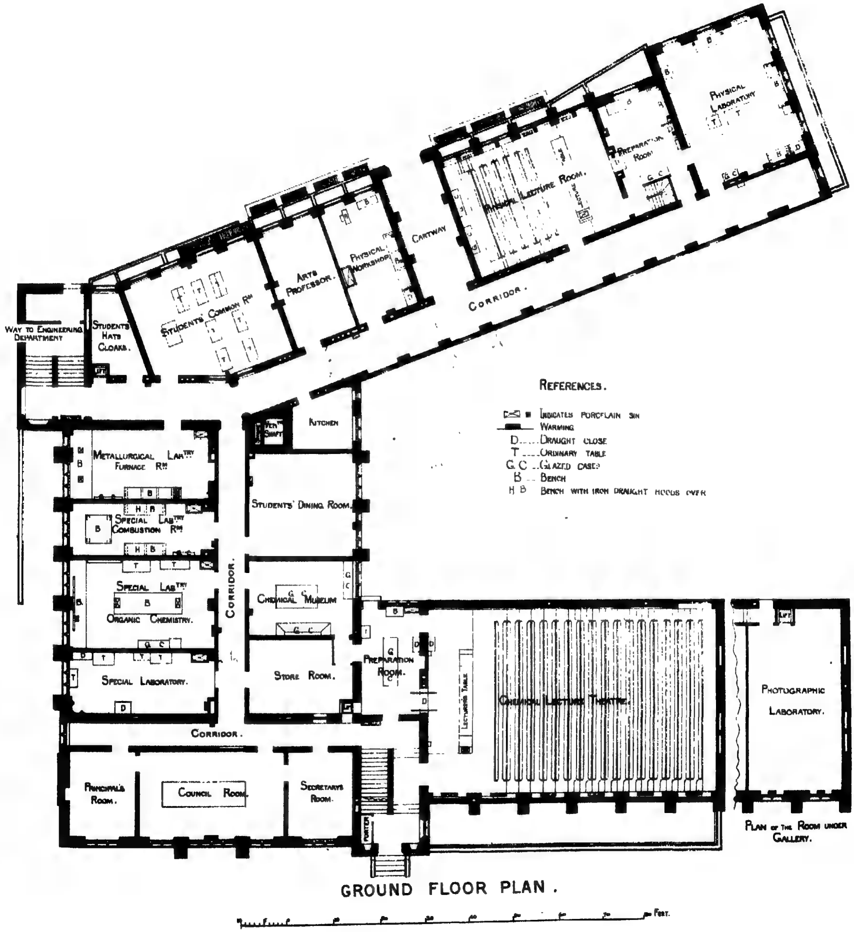


SECOND FLOOR PLAN.

E. N. CLIFTON, ARCHITECT.

THE YORKSHIRE COLLEGE, LEEDS.

CHEMICAL LABORATORY AND BAINES' MEMORIAL BLOCKS.

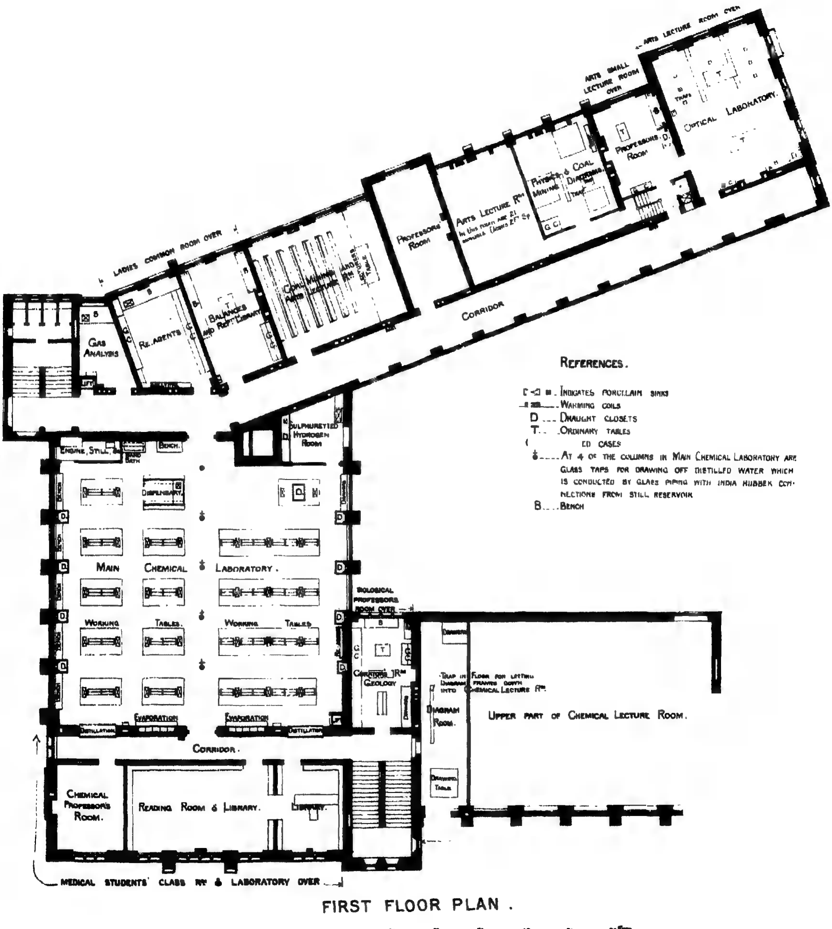


GROUND FLOOR PLAN.

A. WATERHOUSE, R.A. ARCHITECT.

THE YORKSHIRE COLLEGE LEEDS.

CHEMICAL LABORATORY AND BAINES' MEMORIAL BLOCKS.

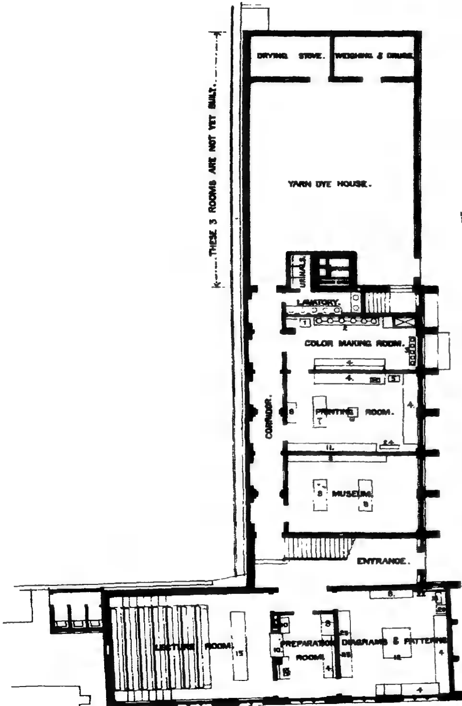


FIRST FLOOR PLAN.

I. WATERHOUSE, R.A. ARCHITECT.

THE YORKSHIRE COLLEGE LEEDS.

DYE DEPARTMENT.



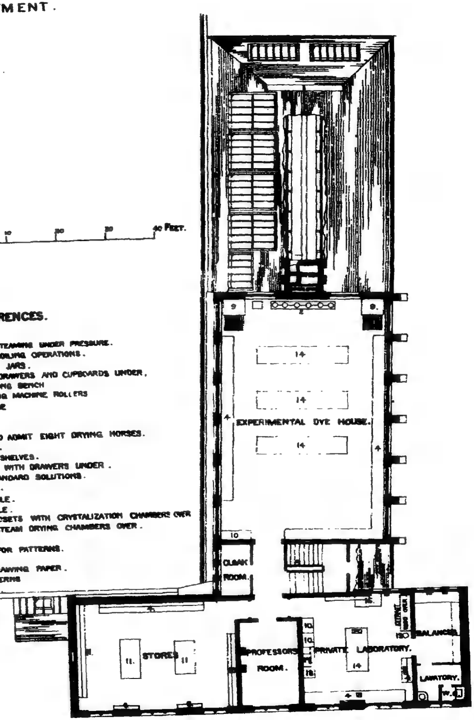
GROUND FLOOR AN

FIG. I.

10 5 0 10 20 30 40 FEET.

REFERENCES.

1. STEAM CHEST FOR STEAMING UNDER PRESSURE.
2. STEAM PANS FOR BOILING OPERATIONS.
3. PRINTING LIQUOR JARS.
4. TABLE TOP, WITH DRAWERS AND CUPBOARDS UNDER, USED AS A WORKING BENCH
5. STAND FOR PRINTING MACHINE ROLLERS
6. PRINTING MACHINE
7. ORDINARY TABLE
8. GLAZED CASE.
9. DRYING STOVE TO ADMIT EIGHT DRYING HORSES.
10. DRAUGHT CLOSET.
11. CUPBOARDS AND SHELVES.
12. DRAWING TABLE WITH DRAWERS UNDER.
13. BURETTE OF STANDARD SOLUTIONS.
14. WORKING TABLE.
15. LECTURER'S TABLE.
16. BLOW PIPE TABLE.
17. EVAPORATION CLOSETS WITH CRYSTALIZATION CHAMBERS OVER
18. SAND BATH & STEAM DRYING CHAMBERS OVER.
19. GAS RESERVOIR
20. STEAM PRESS FOR PATTERNS.
21. CUPBOARD
22. ROLLER FOR DRAWING PAPER.
23. CASE FOR PATTERNS
24. DRYING HORSE.

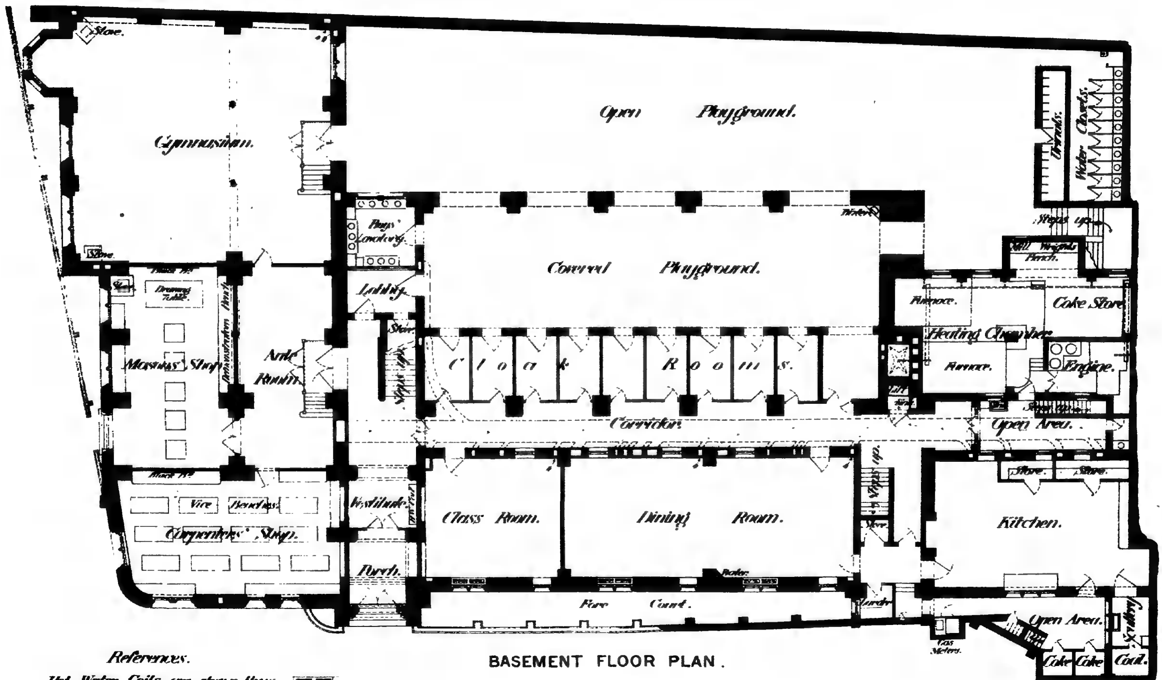


FIRST FLOOR PLAN.

FIG. 2.

A. WATERHOUSE, R.A. ARCHITEC

MERCHANT VENTURERS' SCHOOL, BRISTOL. PLATE 21.



BASEMENT FLOOR PLAN.

References.

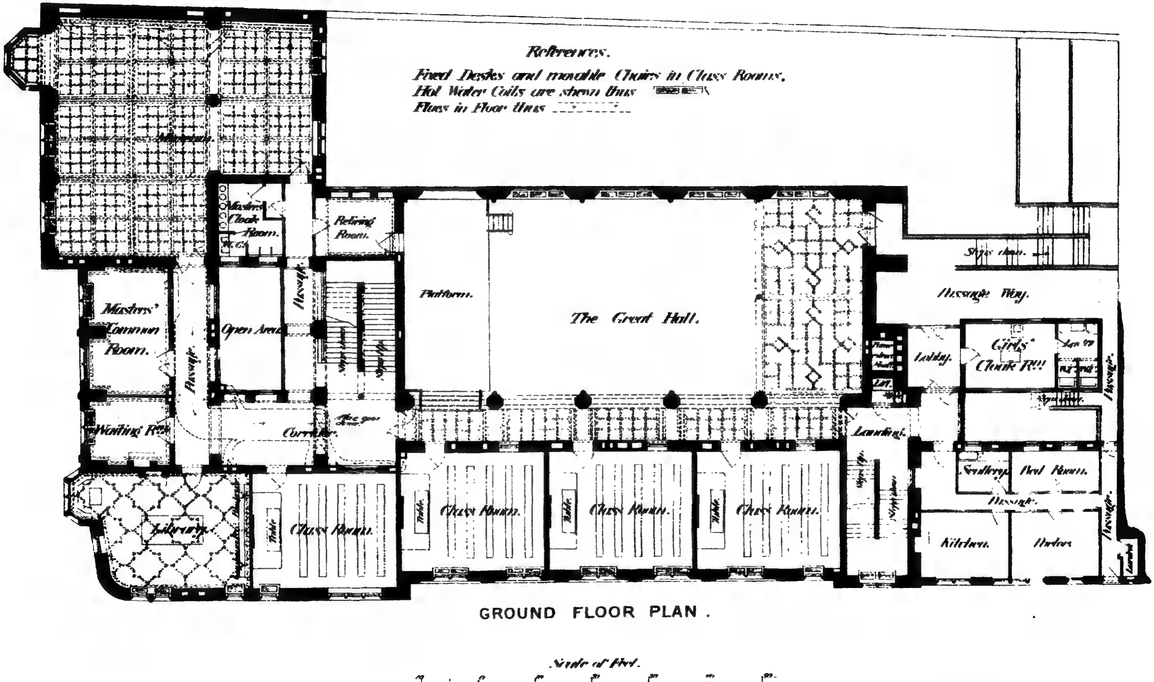
Hot Water Coils are shewn thus

Flues in Floors shewn thus

Scale of Feet.

E.C. ROBINS, F.S.A. ARCHITECT.

MERCHANT VENTURERS' SCHOOL, BRISTOL. PLATE 22.



GROUND FLOOR PLAN.

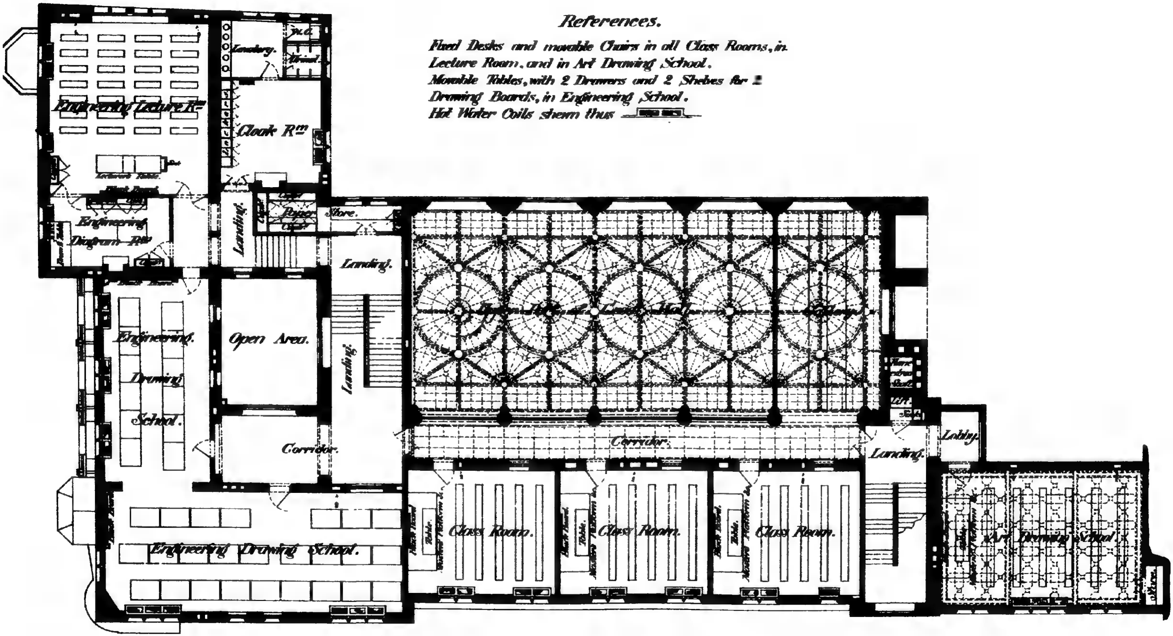
E.C. ROBINS, F.S.A. ARCHITECT.

MERCHANT VENTURERS' SCHOOL, BRISTOL.

PLATE 23.

References.

Fixed Desks and movable Chairs in all Class Rooms, in Lecture Room, and in Art Drawing School.
Movable Tables, with 2 Drawers and 2 Shelves for 2 Drawing Boards, in Engineering School.
Hot Water Coils shewn thus



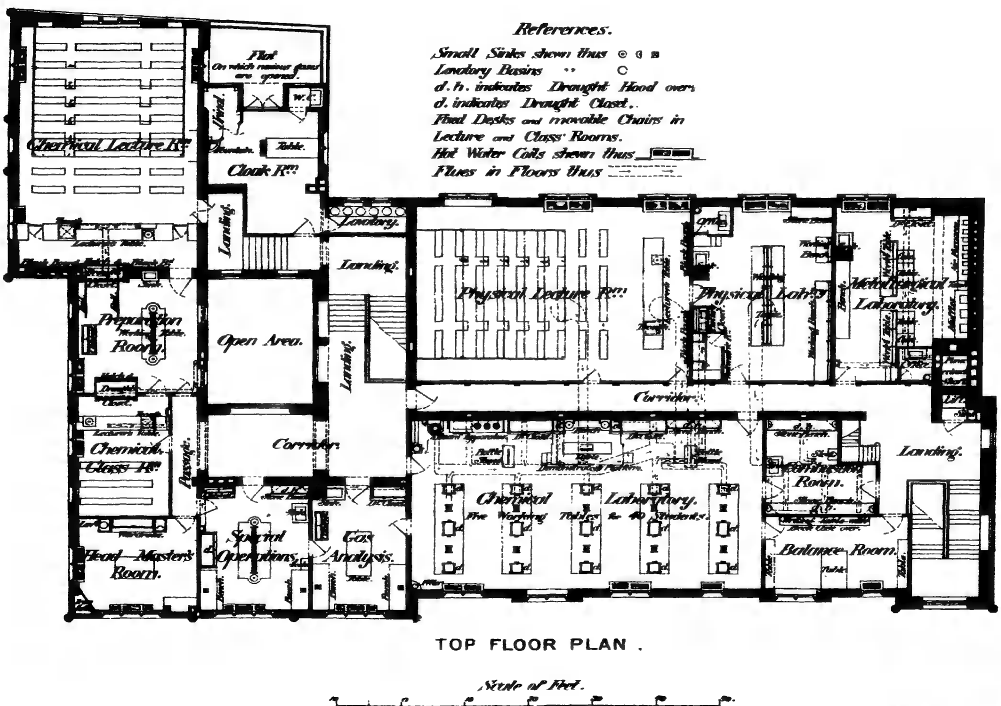
FIRST FLOOR PLAN.

Scale of Feet: 10 0 10 20 30 40 50.

E.C. ROBINS, F.S.A. ARCHITECT.

ERCH ENTURERS' SCHOOL, BRISTOL.

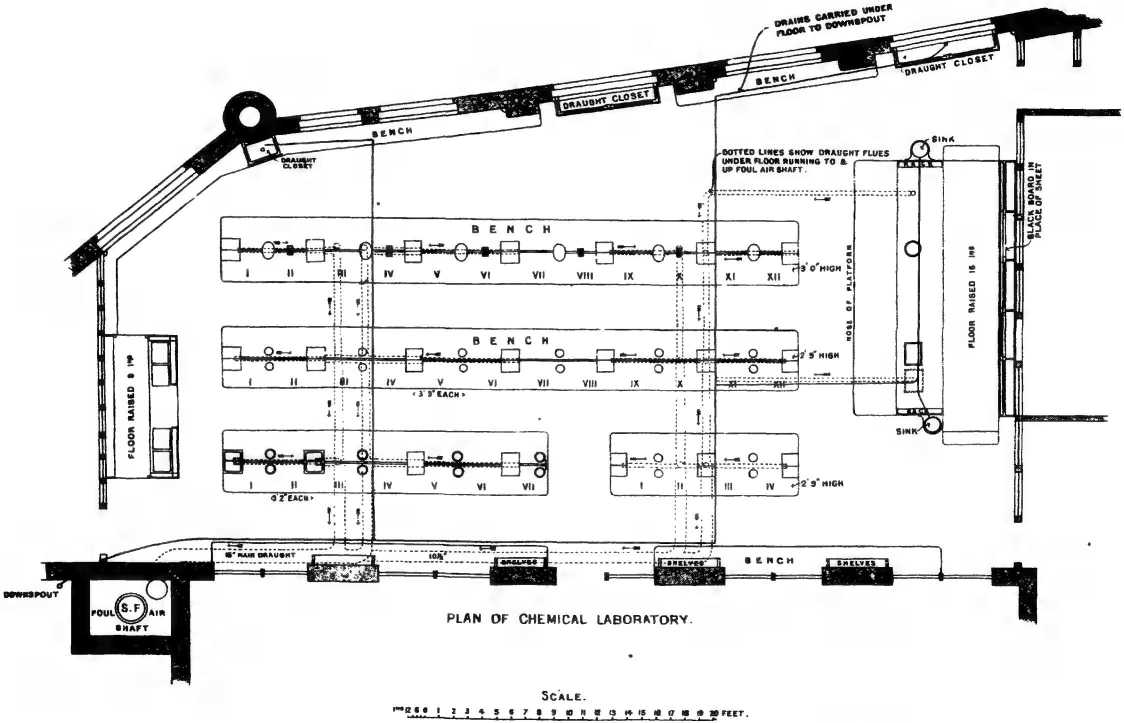
PLATE 24



TOP FLOOR PLAN.

E.C. ROBINS, F.S.A. ARCHITECT.

MANCHESTER GRAMMAR SCHOOL.

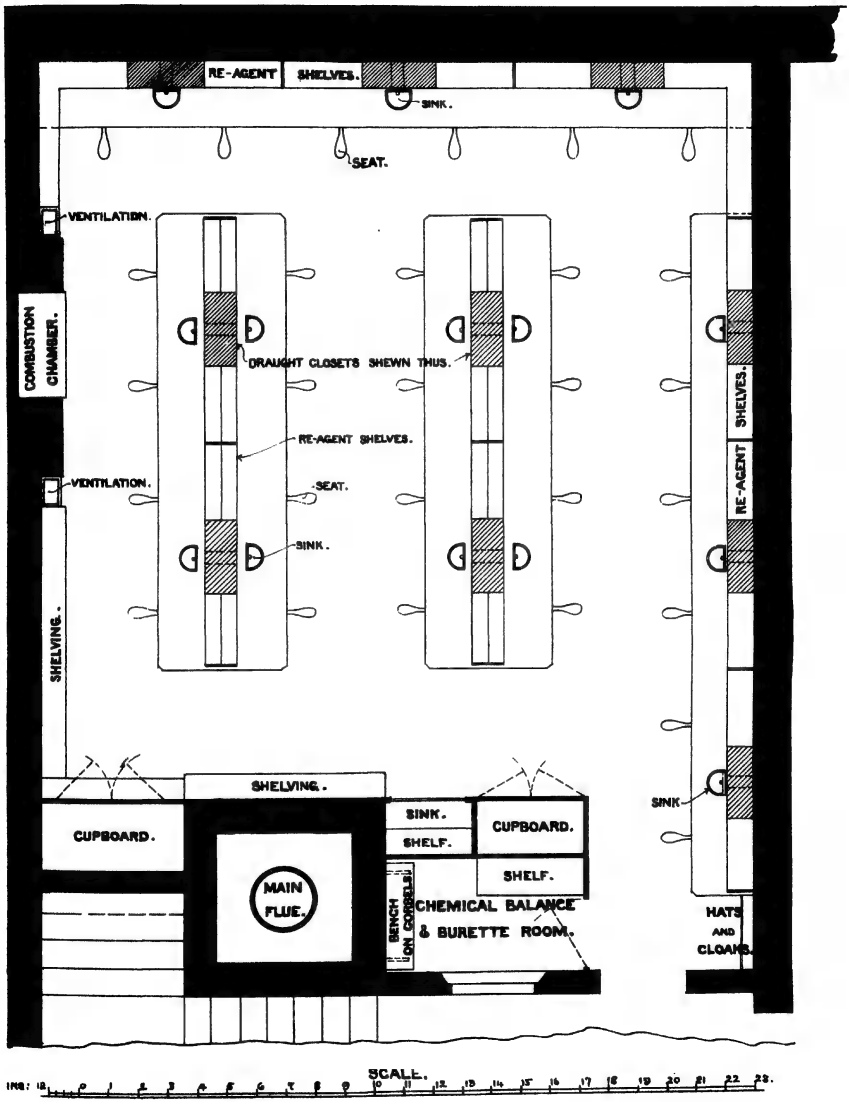


PLAN OF CHEMICAL LABORATORY.

MILLS & MURGATROYD, ARCHITECTS.

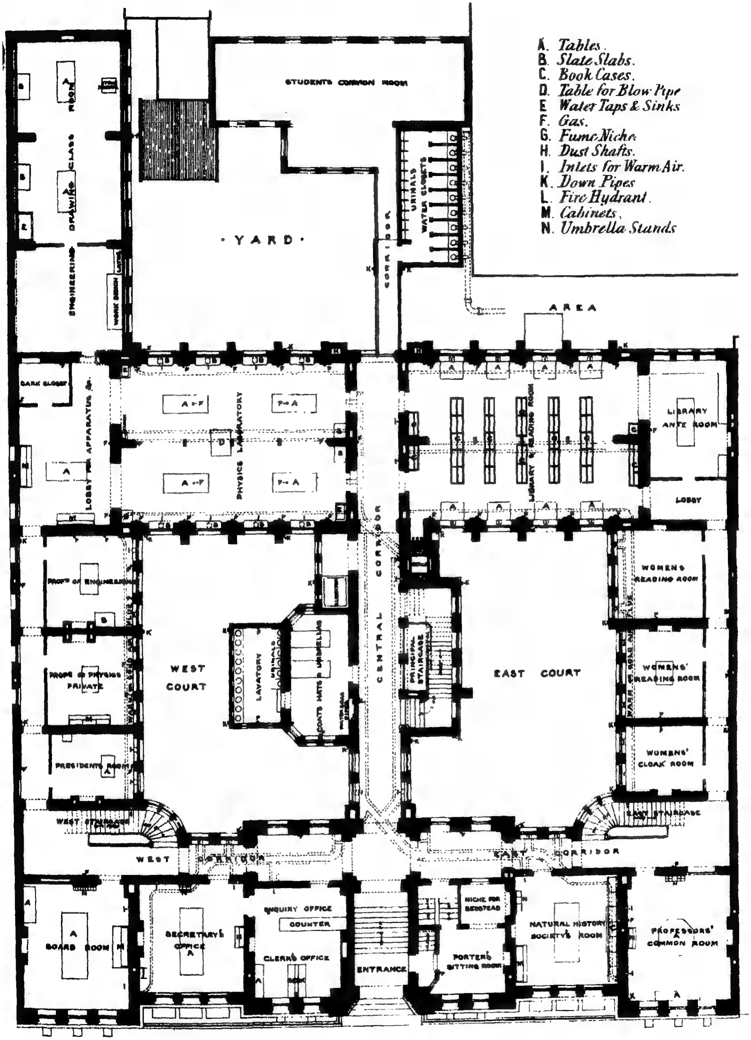
OLDHAM SCHOOL OF SCIENCE AND ART. PLATE 26.

PLAN OF CHEMICAL LABORATORY.



BIRMINGHAM: MASON'S SCIENCE COLLEGE.

PLATE 27



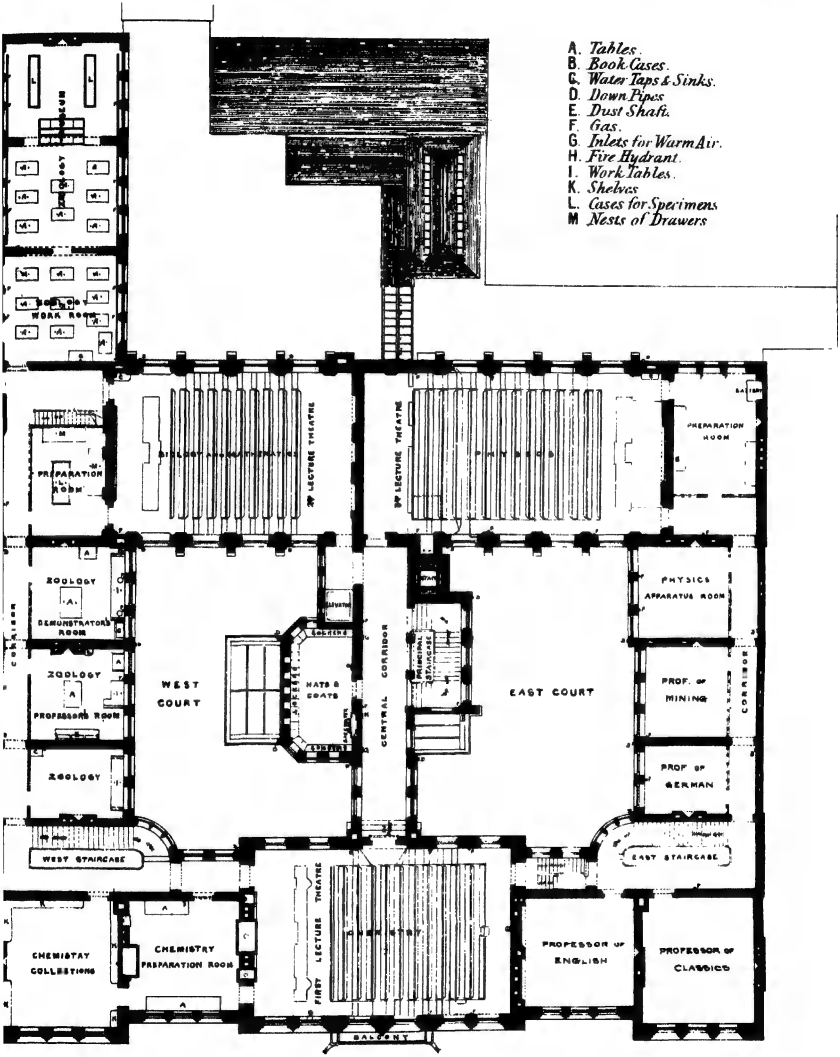
A. *Tables.*
B. *Slate Slabs.*
C. *Book Cases.*
D. *Table for Blow Pipe*
E. *Water Taps & Sinks*
F. *Gas.*
G. *Fume Niche*
H. *Dust Shafts.*
I. *Inlets for Warm Air.*
K. *Down Pipes*
L. *Fire Hydrant.*
M. *Cabinets.*
N. *Umbrella Stands*

GROUND FLOOR PLAN.

SCALE OF FEET.
0 12 24

J. A. COSSINS, ARCHITECT.

BIRMINGHAM: MASON'S SCIENCE COLLEGE. PLATE 28.



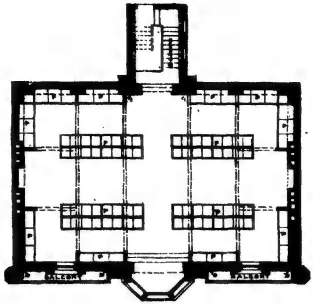
SCALE OF FEET.
0 12 24

FIRST FLOOR PLAN.

J. A. COSSINS, ARCHITECT.

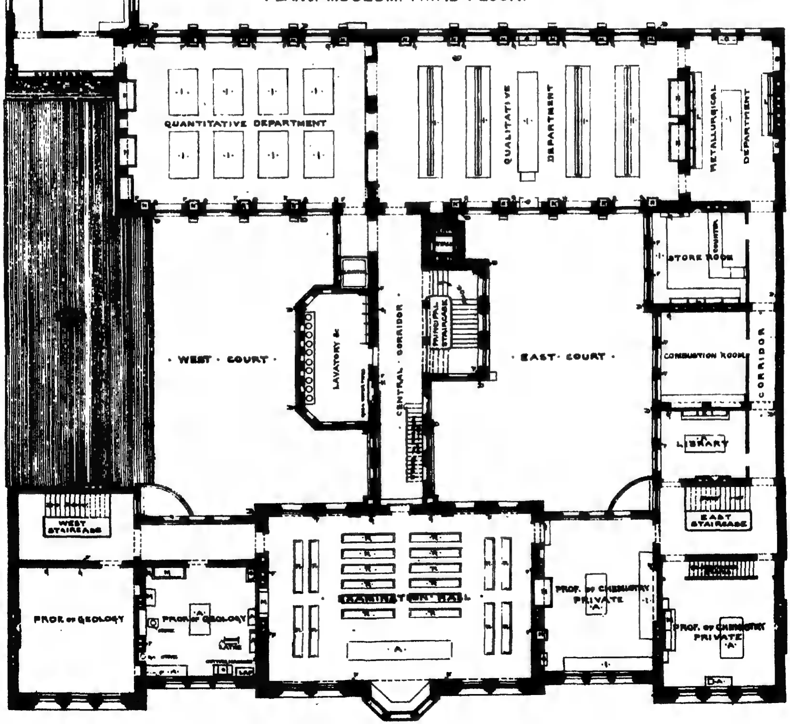
BIRMINGHAM: MASON'S SCIENCE COLLEGE.

PLATE. 29.



A TABLES.
B BOOK CASES
C WATER TAPS AND SINKS.
D DOWN PIPES.
E. BOOK CASES.
F ...GAS.
G ..INLETS FOR WARM AIR.
H .FIRE HYDRANT.
I. WORK TABLES.
K.. SHELVES.
L ..BOTTLE RACKS.
M CABINETS.
N.. STINK NICHES
P CASES FOR SPECIMENS
R SEATS.

PLAN OF MUSEUM. THIRD FLOOR.



SECOND FLOOR PLAN.

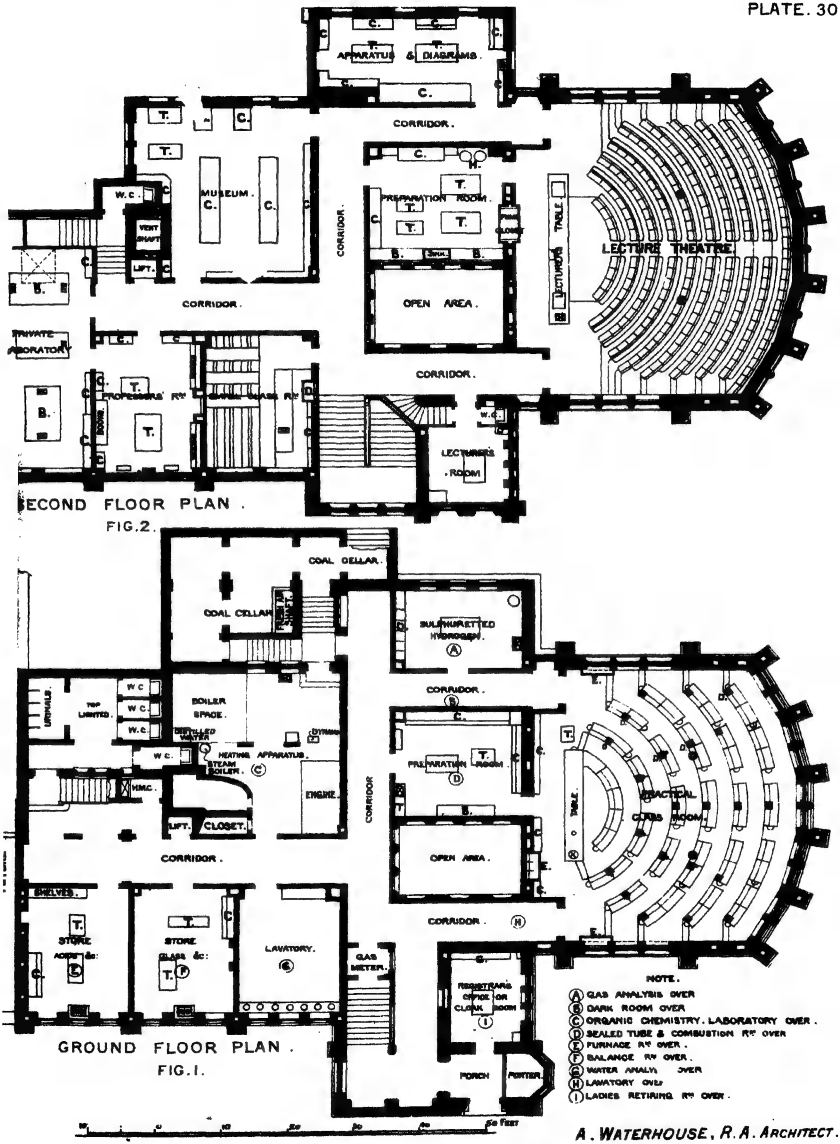
Scale of Feet.

12 0 12 24

J. A. Cossins, Architect.

LIVERPOOL. UNIVERSITY COLLEGE.

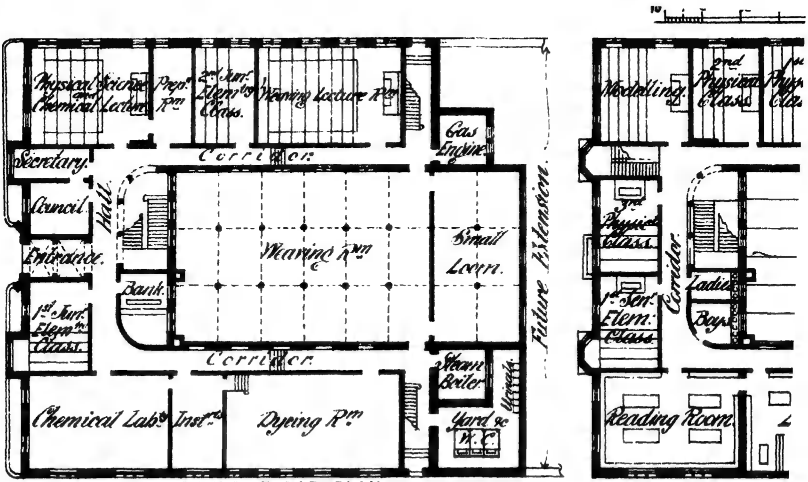
PLATE. 30.



SECOND FLOOR PLAN.
FIG. 2.

GROUND FLOOR PLAN.
FIG. 1.

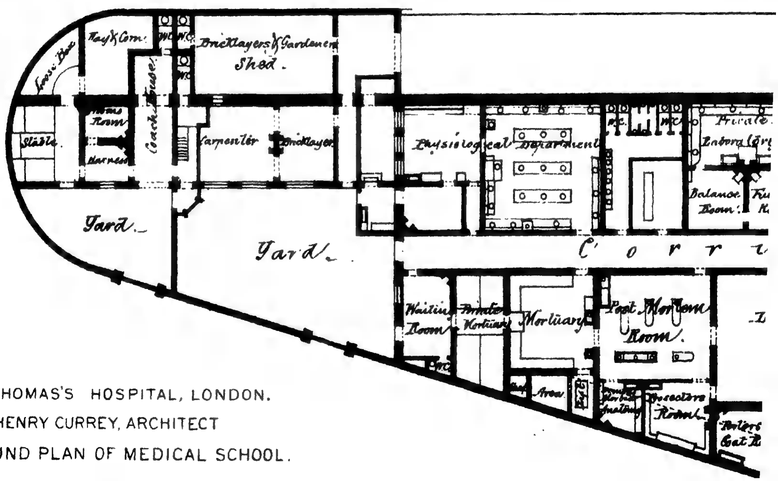
A. WATERHOUSE, R.A. ARCHITECT.



GROUND FLOOR PLAN.

FIG. I.

FIRS



ST THOMAS'S HOSPITAL, LONDON.

HENRY CURREY, ARCHITECT

GROUND PLAN OF MEDICAL SCHOOL.

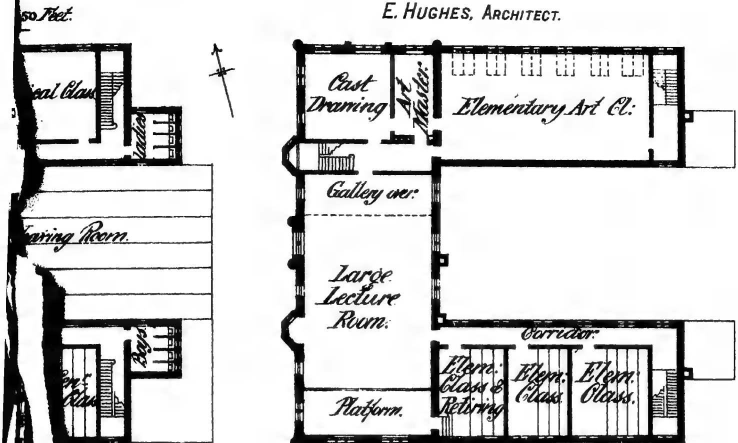
FIG. 4.

N

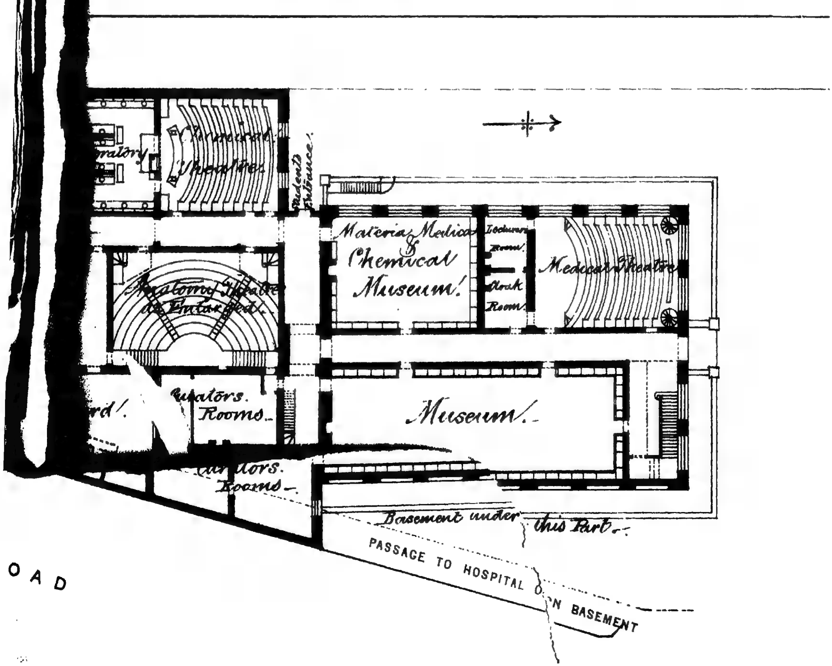
10 0 10 20 30 40 50 60 70 80 90 100. FEET

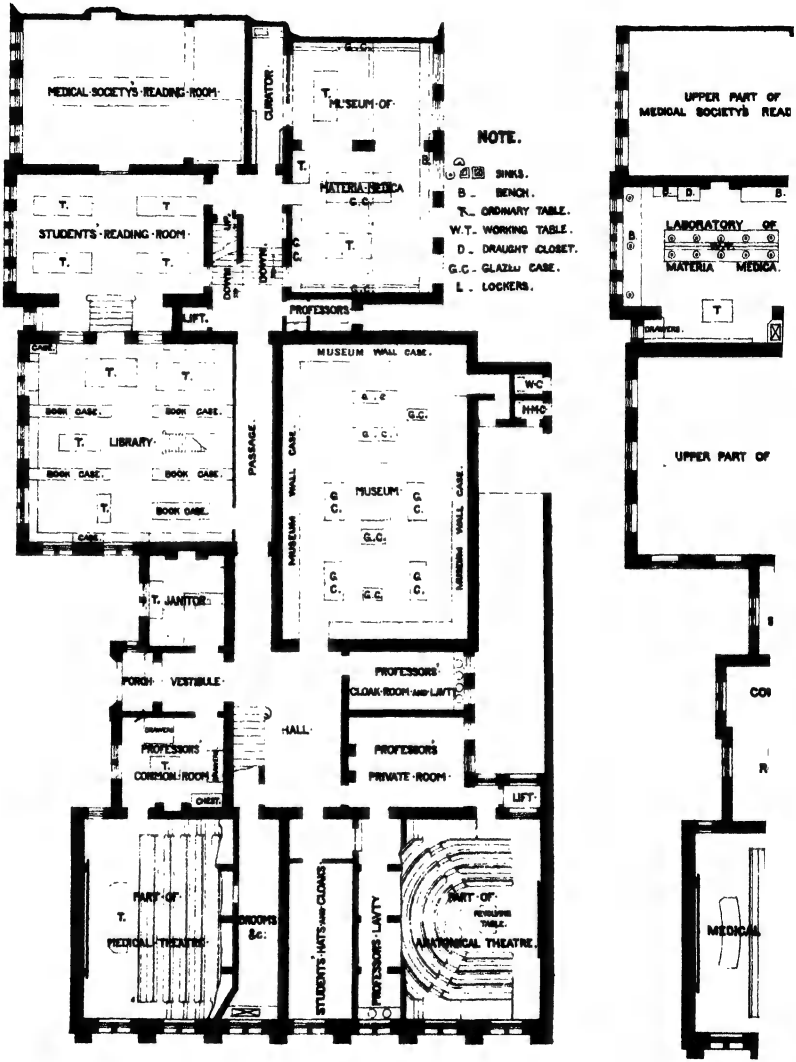
AND MECHANICS' INSTITUTION.

E. HUGHES, ARCHITECT.



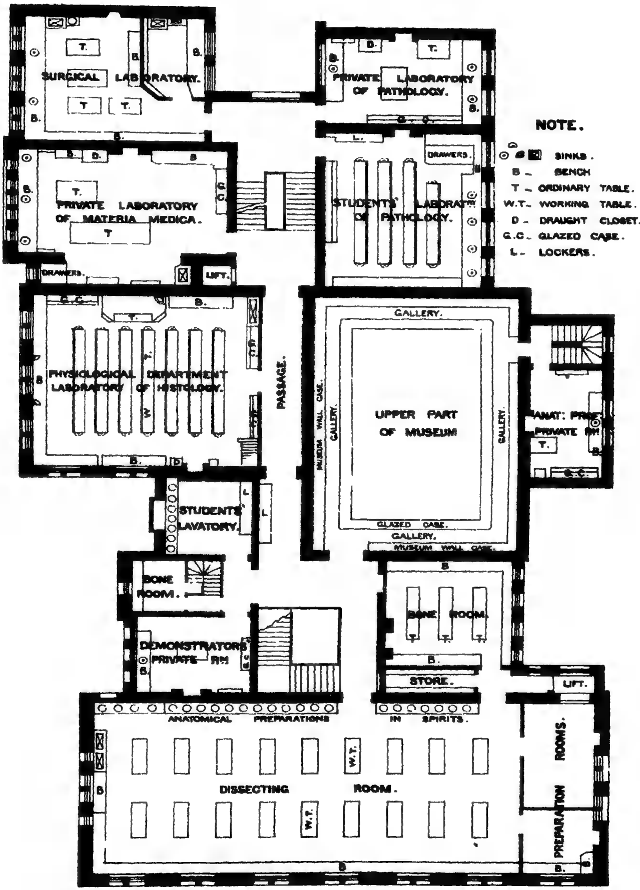
SECOND FLOOR PLAN.
FIG.3.





GROUND FLOOR PLAN.

FIG. I.



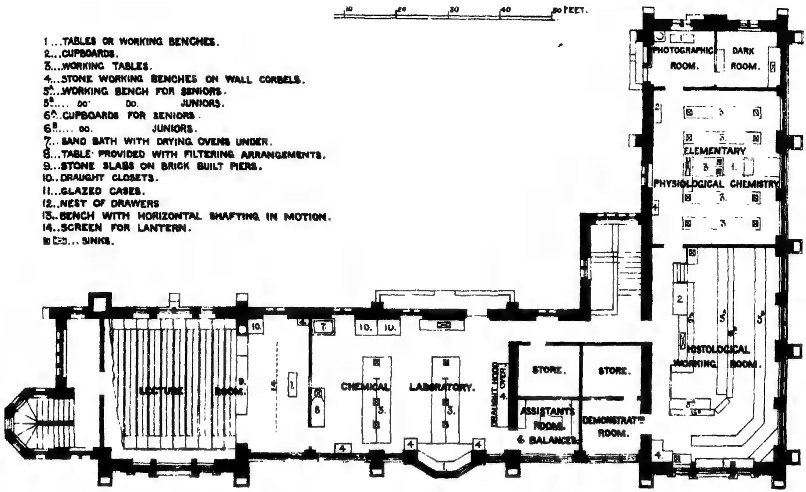
FIRST FLOOR PLAN.

A. WATERHOUSE, R.A. ARCHT

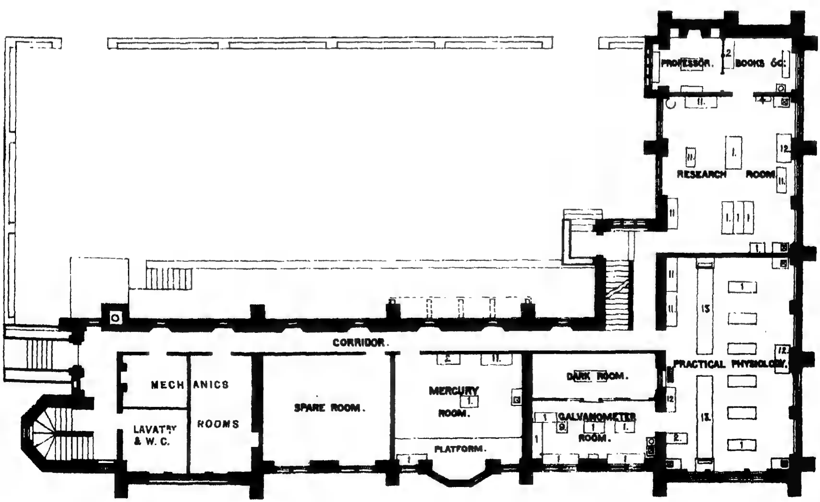
PLATE 33.

OXFORD PHYSIOLOGICAL LABORATORY.

1...TABLES OR WORKING BENCHES.
2...CUPBOARDS.
3...WORKING TABLES.
4...STONE WORKING BENCHES ON WALL CORBELS.
5A...WORKING BENCH FOR SENIORS.
5B.... DO. DO. JUNIORS.
6A.CUPBOARDS FOR SENIORS.
6B.... DO. JUNIORS.
7...SAND BATH WITH DRYING OVENS UNDER.
8...TABLE PROVIDED WITH FILTERING ARRANGEMENTS.
9...STONE SLABS ON BRICK BUILT PIERS.
10..DRAUGHT CLOSETS.
11...GLAZED CASES.
12..NEST OF DRAWERS
13..BENCH WITH HORIZONTAL SHAFTING IN MOTION.
14..SCREEN FOR LANTERN.
... SINKS.



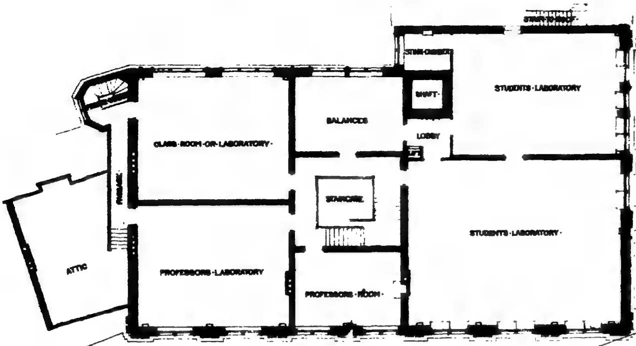
FIRST FLOOR PLAN.
FIG. 2.



GROUND FLOOR PLAN.
FIG. 1.

T. N. DEANE & SON, ARCHITECTS.

SCALE OF FEET.



FIRST FLOOR PLAN.

FIG. 2.

Ⓐ PRIVATE·LABORATORY·OVER

Ⓑ BALANCE·ROOM AND LIBRARY·OVER·

Ⓒ METALLURGY·UNDER·

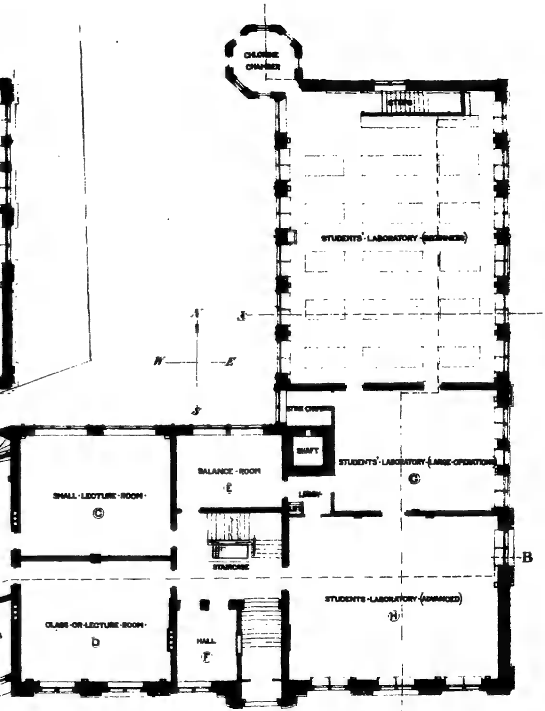
Ⓓ COMBUSTION·ROOM AND ORGANIC ANALYSIS·UNDER·

Ⓔ GAS·ANALYSIS·OVER·

Ⓕ LAVATORY·UNDER — PROFESSORS PRIVATE·ROOM·OVER·

Ⓖ BOILERS·UNDER·

Ⓗ MACHINERY UNDER·



GROUND FLOOR PLAN

FIG. 1.

J VENSON,

CHAPTER V.

THE GENERAL PRINCIPLES AND PRACTICE IN REGARD TO FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS.

IN the previous chapters I have called attention to a series of very interesting English and foreign buildings erected for applied science and art instruction, but only incidental reference was made to the fittings of the various buildings therein described. The subject of the general arrangement of rooms, and their relation to each other and the several departments having been considered, I now proceed to give a particular description of the fittings required for their effective use. I am the more willing to do so, because it is of the utmost importance in a truly economic aspect of the question that the architect and his employers should possess, from the very outset, a clear preconception of the structural provisions involved in the adoption of the particular system of fittings intended; and I must here premise that it is not, I venture to think, to the interest of promoters of buildings for science instruction to ignore the valuable suggestions of the men who will have to impart the instruction for which the whole expenditure is made, nor to treat as mere "whims" the practical outcome of their careful study and comparison of the best means and appliances available.

In my anniversary Address to the Sanitary Institute of Great Britain in 1882, I endeavoured to make clear that there was a work of research to be done by the teachers of pure science which architects could not be expected to include in the numberless subjects already engaging their attention and absorbing their energies, which nevertheless their constructive faculties and powers of adaptive design were best calculated to utilise for the benefit of the community when once they had grasped the scientific principle involved. Since then I have seen the Address of Professor Stuart of Cambridge, at the inaugural meeting of the Dundee University, wherein, under the head of "Modern demand for Technical Instruction," he says:—"But now we have come to a time when there is again a great change in human knowledge. The material part of human life calls for its scientific treatment, and is capable of it.[1] This is the age of a new University move-

[1] The Universities of Germany, through the influence of Liebig, have long since taken the lead in the culture of the natural sciences. The Polytechnics supplement them, but consequent upon this breadth in University teaching referred to by Professor Stuart, and the increasing honour paid to the study of science and its applications to various industries, added to the greater prestige attaching to University degrees, the Polytechnics no longer present such exceptional advantages, and in all probability they will eventually be absorbed by the Universities to make room for a new class of technical institution of lower grade, which event it would be wise for us to anticipate.—E. C. R.

ment, which, in all directions, is manifesting itself either by additions to existing Universities or by the foundation of new ones. The buildings of the past are only the quarry, and not the model for the new buildings you are to erect."

PHYSICAL LABORATORIES.

The great desideratum of a physical laboratory is a steady working-table, and this is difficult to secure. Stone brackets and stone or slate tables built into the walls, with and without stone brackets underneath, are common; and solid piers, brought up from the basement to about 3 feet from the floor, are also quite usual; but Professor Ayrton encloses certain of the tables on these solid bases, distinct from the general flooring, in glass cases as working-benches, the window having rising sashes, which can be raised while working, but closed, locked and kept free from dust and meddlesome fingers at other times. He also designed for Japan a students' gallery for the lecture-room, in which solid piers from below were carried up to sustain the working-benches at the different levels of gallery staging, making it possible for the students to repeat the professor's experiments without leaving their places; thus the lecture-room became also a laboratory, and was surrounded with cases for the collections of instruments, &c. In every town, however, the solid soil trembles more or less, and the brick piers themselves, even on concrete foundations, vibrate. To overcome this, many suggestions have been made: that they should be more deeply founded, and surrounded by an area with or without water filled in, so that the top surface of the ground should not be in contact, and recently, also, a professor has proposed that stout lead should be laid in the joints in place of mortar, and the piers built of stone blocks. Test experiments are being made at South Kensington in reference to this difficult matter.

The result of these tests so far as they have gone is in favour of laying the stone landing which covers the brick pier tables on 4 inches of cotton wool.

Professor Carey Forster thinks the requirements of physical laboratories are more difficult to treat, from a general point of view, than those of chemical laboratories, seeing that the operations are of a more varied kind.

The routine work of a students' laboratory for chemistry mainly consists in analytical operations which do not require a great deal of space, and for which the arrangements in the case of all the students are very similar; but in the physical laboratory a variety of subjects is dealt with: experiments with light, heat, electricity or sound, all these different subjects require special arrangements in order that the operations may be properly carried out; and very often, even an elementary operation, such as would be put in the hands of a beginner on the subject, may require a very great deal of room. In a physical laboratory steady supports must be had, independent of any shaking of the room due to traffic outside the building or to people walking about in the building itself. How this steadiness is to be obtained when the ground itself is in a tremor is a difficult matter, and the professor suggests that it may be possible to obtain it by means of floating supports. Experiments of this kind have been made by Professor Ayrton without success.

Professor Thorpe remarks that steadiness in buildings not originally arranged for the purposes of a physical laboratory is still more difficult to secure, and states that Professor Andrews of Queen's College, Belfast, had made experiments in which a high degree of steadiness was necessary. He found the college buildings not adapted to his work, but he obtained a sufficient degree of steadiness by introducing underneath the floor heavy wooden beams, on which all the apparatus necessary was directly placed, so that the experimenter in walking over the floor (the floor being entirely disconnected from those beams) only gave the smallest possible tremor to the apparatus.

CHEMICAL LABORATORIES.

In the description and critical analysis of the fittings of chemical laboratories, upon which a considerable amount of ingenuity has been displayed, I have been greatly assisted by my friend Professor Armstrong ; if, quite unintentionally, I seem to speak dogmatically it is due to the results of consultations with him and many other eminent chemists, among whom I should mention Professor Roscoe, Dr. Perkin, Professors Thorpe, Ramsay, Tilden, Carnelly, Clowes, Fisher, McLeod, and Jones, as having given me valuable aid. Messrs. Waterhouse, Clifton, Murgatroyd, Cossins, Eagles, Ireland and Maclaren, and other architects, have furnished me with illustrations of their works.

I.—WORKING-BENCHES AND THEIR FITTINGS.

(*a*) *Dimensions and distance apart.* The dimensions of the benches in a laboratory intended for the ordinary operations of qualitative and quantitative chemical analysis, and the distance between the benches (that is, the width of the gangways) must necessarily depend more or less on the space at disposal. In all the best laboratories, and invariably in Germany, they are placed at right angles to the windows in the flank walls.

The chief points to be borne in mind are : 1. *That the bench should be of such a depth that the student can without difficulty reach from front to back, say 2 feet 3 inches.* 2. *That the top of the bench should be at such a height above the floor level that the student standing at the bench can carry out the various ordinary operations of filtering, &c., without raising his elbow much above its natural position, say 3 feet.* 3. *That the benches should be sufficiently far apart to admit of at least one person passing between the students who are working back to back at contiguous benches, say 4 feet 6 inches to 5 feet.*

With reference to the first and second points, it is obvious that, since there is a considerable variation in the length of reach and height of different individuals, only the average requirements in these respects can be met in the case of public laboratories; for these must necessarily accommodate a variety of students. As a rule, it is only in school laboratories that the very special requirements of a particular class of students can be consulted. In institutions where separate rooms are provided for beginners and advanced students, it has been usual to afford greater space to the latter class. As a matter of fact, however, I am informed that the beginner has often to deal with larger apparatus than the advanced student of quantitative analysis. Be this as it may, it is not improbable that in

future the work of the beginner and of the advanced student will tend more and more to approximate in character, and to differ rather in the extent and thoroughness with which similar subjects are studied. The architect consequently may not be called upon to perpetuate the system which has hitherto prevailed.

(*b*) *Drawers and cupboards, &c.* The space under the working-bench is always fitted with drawers and cupboards, which necessarily vary in number and size. The character of the arrangements commonly met with may be seen at Leipsic, Owen's College, Finsbury College, Central Institution, Merchant Venturers' School, Bristol, and Manchester Grammar School (see Plates 46, 35, 37, 40, 39, and 36). Usually at least two cupboards and two drawers are fitted in the space allotted to each student's use, or a drawer and cupboard may be assigned to each of two students attending at different times. Except in the case of students engaged in research, no other provision is required. A long narrow drawer extending across the entire double bench as at Leipsic and Manchester and the Yorkshire College is of the greatest use to advanced students for storing long tubes, &c. The cupboards are generally fitted with one or at most two shelves, but it is desirable that one or both of them should not extend the whole distance from back to front, in order that tall articles may be put away. Open niches take the place of cupboards in some cases. To minimise the number of locks and keys, several devices have been introduced. At Leipsic the two cupboards and two drawers are kept closed by means of a T-shaped piece of brass and a single lock. At the Firth and Finsbury Colleges, the drawer has no lock, but is kept closed by an oaken spring beneath it, so that only the cupboard doors have to be unlocked and the spring pushed up, which the student does in commencing work. The bottom of the cupboard should be raised a few inches, and space for the forepart of the foot be thus provided as at the Manchester Grammar School. In some cases the cupboard fronts are themselves set back 4 or 5 inches from the front edge of the bench top.

(*c*) *Materials employed.* Either deal or pitch pine, according to the funds at disposal, is almost invariably employed for all but the bench top. At the Nottingham University College, American walnut has been largely used.

Considerable diversity is met with in the treatment of the bench top. It need scarcely be stated that the materials employed should be as durable and impervious as possible, having little tendency to absorb liquids, to be stained, or to shrink and crack under the influence of heat radiating from the burners employed in heating flasks, &c. Pine, deal, beech, oak, mahogany, teak, nut and American walnut have been used. The last only at Nottingham, and nut only at Geneva. Deal is commonly used from economical motives, but it is probable that the economy is more apparent than real. Most tops are oiled only, as required; all woods for bench tops are improved by ironing-in ordinary solid paraffin with a box-iron, or better still a gas-iron. Paraffin has the great advantage over oil or wax that it resists the action both of acids and alkalies. Oil and wax are readily affected by alkalies and slowly even by acids. The only objection to paraffin is that it melts under a heated sand-bath or when a hot flask is placed on the bench, but a small square of Asbestos cardboard, and a few small squares of carpet or felt supplied to the student meet this difficulty. Of the hard woods above mentioned, teak appears to be the best. Professor Roscoe, of Owen's College (where the bench tops are of

oak), says that he would prefer teak. The bench tops at the Finsbury College are covered with seven pounds of lead. Lead is used at Bristol University College; and it is also employed, and highly approved of, in all the numerous laboratories of the Badische Anilin and Soda Fabrik, where some thirty chemists are actively engaged in research and in technical analysis. It is said that lead "blows up" underneath heated objects, and that glass apparatus, &c., in use in chemical laboratories is more easily broken when set down upon it. The former difficulty is easily overcome by the use of Asbestos cardboard, and the latter Dr. Armstrong assures me is entirely imaginary. The best mode of fixing the lead in front is to bend it down over the perfectly square edge of the table top, and, after lightly copper-nailing it, to fix a rounded fillet of hard wood to the edge of the bench top, bedded in red and white-lead putty, before screwing up. In private laboratories, glass and slate have been used, but these are not suited to average requirements. The edge of the bench top should overhang one or two inches.

(*d*) *Sinks.* It is customary to provide sinks, about 9 inches in diameter, in the benches for beginners, as has been the case at Owen's College, the Manchester Grammar School, and the Yorkshire College, and they are usually placed so as to be accessible to students on both sides of a double bench, and serviceable to four students. These sinks are in some cases circular, in others oval or oblong. For advanced students the sinks as a rule are placed at the ends of the benches, as at Owen's College. At the Finsbury College there is a sink at each end of the senior students' benches, but no sinks are attached to the benches which are chiefly intended for the use of "occasional students," but a long demonstration-table on a raised platform runs at right angles to these benches, and in front of this is a lead-lined sink, 16 feet long by 12 inches wide, and 12 inches deep, with a cistern under the top of the demonstration-table (Plate 38); this upper tank is kept filled by the ball tap, and thus the water is delivered from the taps at a constant low pressure, and splashing avoided. In this case the students must leave their places whenever they wish to wash their apparatus, but the distance is short and there is ample accommodation for eight students at the sink. If the sink be on the bench it is difficult to avoid splashing.

Sinks are constructed of various materials—of porcelain, stoneware, enamelled iron, wood, and lead. Stoneware and porcelain are most commonly employed; they are easily kept clean, and if properly glazed will resist chemical action, but they are easily broken both by falling objects and very hot liquids. The best illustration of the use of wood is at Munich, where oval-shaped, iron-bound, oaken tubs are found, made narrower at the top than the bottom to check splashing, and these appear to answer well. Lead sinks do not look so neat as porcelain basins, but they are not so easily damaged; they should, however, be constructed without the use of solder, and there should be a good fall towards the outlet, otherwise the lead may decay rapidly through corrosion. At the Manchester Grammar School, and at the Yorkshire College, the sinks empty into a V-shaped open drain to outfall.

(*e*) *Re-agent shelves and upper works.* In nearly every laboratory hitherto constructed, a rack of shelves to hold re-agent bottles is placed along the centre of the bench, and is either fixed or moveable, the shelves being about 6 inches wide and 9 inches apart. In some cases a hinged or sliding glazed front is

fitted to these racks, as at Owen's College and at Dundee, or revolving shutters are lowered over all, as at Berlin; but this addition is of doubtful utility. In the medical schools at Owen's College the shelves are not closed. At Graz two distinct glazed cupboard fronts are provided; one enclosing the bottles for strong acids, and the other the ordinary re-agents; but this is an unnecessary refinement. At Munich only a single shelf is provided for re-agent bottles, and it is carried on iron standards; this arrangement has the advantage that the students on either side of the bench can see each other and converse; to which Professor Williamson, however, distinctly objects. He has so fitted up his new laboratory at University College, London, that each student is isolated as much as possible from his neighbour: a system which does not commend itself to me, and is nowhere else attempted, besides which the professor cannot thus have an uninterrupted view of the students in the entire laboratory as in the former case. At Bristol College the re-agent shelves are moveable. Professor Schmidt, of the Dresden Polytechnic, has his double benches made in three portions. The re-agent shelves (of which there are two besides the top) there form the central division, underneath which are arranged the pipes and wastes, and the benches on either side form the other two divisions. At the Finsbury College a novel plan has been adapted, the large illustration of which will be fully described further on. The re-agent bottles are placed under the "heating shelf" on a raised ledge down the centre of the bench (Plate 37).

2.—Draught-closets for General Use.

Draught-closets are closets in which operations can be performed which give rise to the production of noxious fumes or gases. Some provision of this kind appears to have been made from the time of Liebig, the first teacher of chemistry; but the original closets were, in most cases, few in number and of large size, being mainly intended for large operations.

Hofmann first introduced the small closet now so universally met with in chemical laboratories, and recommended by the South Kensington authorities.

(*a*) *Position of draught-closets.* The position of the draught-closets intended for operations incidental to ordinary qualitative and quantitative analysis, indicated in the Owen's College, the Dundee,[2] and the Yorkshire College plans may be regarded as typical. In both cases the closets are near to the ends of the students' benches, being, in the one case, fitted in the walls, and in the other, in the piers between the windows. At Munich the closets are formed in the window spaces, by which ample illumination is secured.

(*b*) *Dimensions of draught-closets.* The required sizes are shown in the illustrations of Professor Hofmann's closets[3] constructed at Bonn and Berlin, and Professor Roscoe's wall-closets at Owen's College. Those at Munich are considerably larger, being chiefly intended for use by students engaged in research. Several larger closets are provided at Owen's College, and elsewhere. In all cases, however, the variation

[2] Plates 42 and 19.

[3] Plate 47.

is mainly in length; the depth and height differing but little. The depth of the closet and the distance of the top of the floor of the closet above the laboratory floor are regulated by the same considerations as those to which allusion has already been made in connection with the working-benches in the laboratory. In respect to the height of the closet it is obvious that inasmuch as it is important that the fumes be carried away as fast as possible, it is desirable to reduce the capacity of the closet to its narrowest limits, and therefore it should not be higher than necessary. As ordinarily constructed the closets are too high, because, in the majority of operations which the student in an analytical laboratory has to perform, the apparatus employed rarely, if ever, exceeds 2 feet in height. At Finsbury College the smallest closets are 2 feet 10 inches in height; at Yorkshire College, 2 feet 6 inches; where the students are engaged in research, as at Munich, it is desirable to make a considerable number, if not all the closets, to contain an apparatus some 5 feet high; and in every laboratory one or more such closets should be provided according to the character of the work likely to be carried on. The position of these will necessarily depend on the nature of the space at disposal for the purpose. The average width of the draught-closets is 2 feet; ditto depth, 1 foot 9 inches; ditto height, 2 feet 9 inches; and for the larger draught-closets the average width is 4 feet 6 inches; ditto depth, 1 foot 9 inches; ditto height, 5 feet; height of bottom of closets above floor, 3 feet.

(*c*) *The sashes of draught-closets.* The front of the closet is always enclosed by the rising sashes. The larger the pulleys the easier run the lines, which may, with advantage, be of steel, copper covered. But, better still, the breaking of lines and the provision of pulleys and weights may all be superseded in light sashes by the spring attachments in common use in railway-carriage windows. When the draught-closets are in use, it is necessary to raise the sash a short distance in order to admit air, which causes the gas flame burning within to become deflected. To avoid this, at Leipsic, a small subordinate sash is provided, and thus the width of the air slot and its distance above the closet floor can be regulated. At Manchester, this subsidiary sash takes the form of a small glazed flap hinged to the bottom of the closet. At Berlin, a "hit and miss" arrangement is introduced in some of the larger closets, two sliding glass plates with holes being fixed at the bottom of the closet front. On raising the ordinary rising sash, there is necessarily a space between the inner side of the glass and the upper edge of the closet from which fumes escape. Dr. Armstrong has remedied this by fixing to the top of the closet a kind of "squeege," which scrapes against the plate glass, viz., a lath coated with a double thickness of the best carpet felt, which has been found to answer the purpose completely. India-rubber was at first tried, but this is not only expensive if of sufficient thickness, but it produces considerable friction which ends in twisting, so that it does not preserve a straight line throughout its length.

(*d*) *Materials to be employed.* It is almost more important, in the case of the draught-closets than of benches, that the "top" should be of an impervious material. Slate sandstone and lead are commonly used, the latter being more generally adopted. If, however, stone be used, it is important to select one which is neither readily acted upon by

chemical agents, nor liable to crack when moderately heated. Saturation with paraffin, or many of the solutions used for indurating freestones, would probably render it to all intents and purposes non-porous. In many laboratories provision is made for carrying away the liquids which may be spilt on the floor of the closet, a chase being cut round the edge of the slab, and a pipe being fixed therefrom to the receptacle below. In many cases a jar or other vessel is placed there into which the students throw all solid waste as well. There is some difficulty in securing a proper material for the roof of the closet. Wood is very liable to warp and crack under the combined influence of the heat arising from the burners and acid fumes and moisture. Slate, although not acted upon by acids, &c., is a treacherous material and liable to crack if heated. Glass, which is always used when the draught-closets are in front of the laboratory windows, as at Munich, is less porous than slate, and would, in most cases, be the cheaper material, but it is equally liable to crack. At Strasburg, frames of angle iron have been fitted to the walls and hipped at the angles; upon these a very coarse iron-wire gauze has been stretched, and coated on both sides with Portland cement. The condensation of the vapours under slate, glass, or impervious stone, is an inconvenience which has to be provided against. At Finsbury, the closets have a curved roof of galvanized iron which is coated inside with tar or pitch-varnish. Probably the best and cheapest roof would be made of enamelled iron, which could be cast in one piece, the required size, and be coated with enamel of such a quality that it would resist the action of acids.

(*e*) *The draught-flues.* Fumes, &c., are usually extracted from the draught-closets through a single opening, square or circular, high up in the back of the closet, the draught being produced in the older laboratories, as at Bonn and Berlin, by means of a gas jet burning in the flue. Each closet has a separate flue, and there is no simpler and more generally effective plan than this, where there are no down draughts or cross currents between the flues to upset their steady action. But several, say a row of, closets may be all readily ventilated by one flue, aspirated by one or more "Bunsen" burners. This, I am told by Mr. Waterhouse, has been found to work well at Owen's College, especially where the "Bunsen" is enclosed with a cast iron cone, with an opening at the top, the iron becoming heated by the burning of the gas accelerates the rush of air. Dr. Armstrong's private laboratory is thus ventilated, as I shall hereafter describe, with considerable success. In most of the recently constructed large public laboratories, however, the flues from the various closets, are all connected with a central flue, and the draught is produced either by means of a tall shaft, at the base of which is a furnace, as at both the Manchester examples and at Birmingham, or by means of a fan as at Munich, Geneva, and Aachen, and at the Bristol Trade School.

The question of shaft *versus* fan, will be discussed hereafter in the chapters on heating and ventilating, Nos. VII. and VIII., but it may be well to bear in mind that competing draughts should never be introduced into a chemical laboratory. No two opposite ways should be provided for the escape of air, and as the draught-closets cannot well be too efficient, the whole of the air of the laboratory may be extracted through them, but it is better to have additional outlets.

The introduction of fresh air to the closets, is like introducing fresh air opposite and under a fire-place, it prevents the draught-closet, or the fire and its flue, from withdrawing the expired air from the room for its sustenance; besides which it may permit of air passing into the laboratory whenever the sash of the closet is raised, or it may result in weakening the force of the current of air which should be away from the operator, towards the closet flue. Again, as the closet has a maximum efficiency only when the sash is raised sufficiently to give an opening of about the same area as the area of the flue, it is important that the whole force of the draught should be in one direction, namely, from the operator towards the flue. Professor Schmidt, of Dresden, has removed his closet windows in some cases for ordinary operations, finding them work equally well under the hoods without them.

Professor Carnelly writes from University College, Dundee, to say that he believes the system of ventilation adopted there is exceptional, and that it answers very well indeed, contrary to his own expectations, both as regards heating and ventilation. It consists in blowing the air into the building by five large air-pumps over heated pipes, which escapes up the ventilating-flues and the draught-closets. This is the first application of the principle of forcing the warm and cold air into the general laboratory and not otherwise aspirating the draught-closets, a principle which has been successfully applied to large assembly rooms by Mr. W. W. Phipson.

The current of air in a draught-closet has a maximum force in a direct line with the flue opening, and the other parts of the closet are more or less in "shadow," and vapours hang about them. This may be obviated by making the outlet in the form of a slit (extending along the back of the top of the closet) of equal area to the flue with which it communicates. Very long closets should be provided with trumpet-mouthed slits. Dr. Armstrong has presented us with an example of this kind, which has been constructed in his private laboratory at Finsbury College. It is shown in Plate 50. The closet is 11 feet 9 inches long and 21 inches deep, but it is divided into three compartments, two of these, one at either end, are 4 feet 5 inches long and 2 feet 9½ inches high in the centre of the curved roof, and 2 feet 7 inches high at the back and front. The central compartment is 2 feet 9 inches long and 5 feet 3 inches high; across the entire width, in the rear, a wooden back is fixed about an inch away from the wall, extending to within 9 inches roof, but also having a slit-opening an inch wide 18 inches above the floor, which e closed by a movable slide. The corresponding backs of the end compartments are formed of glass to within 2 inches of the roof. The openings thus formed between the wall and the back of the closets extend downwards into the horizontal box-flue, 13 inches by 13 inches, which is connected with an ordinary 18-inch by 9-inch brick flue built in the wall. The draught is produced by a "Bunsen" gas burner at the base of the shaft, and a velocity of 7 feet per second or about 400 feet per minute in the flue is easily secured by a consumption of about 10 feet of gas per hour.

When draught-closet flues pass directly upwards, it is found that condensed liquid and dirt are very liable to drop down into the closet and vitiate experiments there being performed. To obviate this, Professor Hofmann made the provision shown in Plate 47. These arrangements have been repeated at Owen's College and at Birmingham, and they

are mentioned also in the recommendations of the Science and Art Department at South Kensington. At the Yorkshire College, Professor Thorpe has preferred to have descending flues.

(*f*) *Dr. Armstrong's hood arrangements.* In practice, the closets thus far described, although intended for general use, are, on account of their position relatively to the benches, only made use of by students on special occasions, that is whenever it is necessary to perform an experiment with noxious materials, or one which is likely to produce specially noxious fumes. Consequently the hundred and one experiments in which small quantities of acid vapours, &c., are produced are performed in the open laboratory, to the manifest detriment of the purity of the atmosphere, which is further contaminated by the products of the combustion of one or more gas jets for heating purposes usually kept burning on every student's bench. Dr. Armstrong conceived the idea that this was a very needless and very illogical arrangement and that none of the noxious gases or fumes should be allowed to escape into the room, but on the contrary that all of them should be collected under hoods and carried away, and that the general ventilation of the room should be effected through the same channel. Attempts have been made to bring the draught-closet so near to the student that he should not be tempted to vitiate the atmosphere; and at Aachen, Owen's College, the Bristol School, and the Manchester Grammar School, a small draught-closet is provided on each student's bench, illustrations of which are given. That at the Manchester Grammar School,[4] which was planned by Mr. Francis Jones, the head-master, is especially deserving of attention. As will be seen by the drawings, each closet is 15 inches high by 10 inches by 10 inches area; two such closets are placed back to back, and the flue which is common to both is of porcelain, being ingeniously constructed with a diaphragm down the centre, so that each closet may have its fair share of the "pull." But there is little to enforce the use of this provision when made, and the gas burners are mostly exposed as before. Therefore I view with considerable interest the system which has been initiated by Dr. Armstrong and carried out under his supervision at the Finsbury Technical College,[5] because it promises to afford a satisfactory solution of the problem under consideration. A "heating shelf," 22 inches wide, is fixed 11 inches above the bench, and over this is a hood 24 inches wide of the shape and size shown. At intervals of 4 feet under this hood, 4 inches square, iron down-cast flues, pitched inside, are connected with the horizontal flue channels in the floor. Wing plates are attached to these down-cast flues, forming a continuous extract-flue opening, extending the whole length of the hood. By raising and lowering these plates, by means of the screws at B B and B, the width of the opening can be graduated at will, and made wider at B than at A A in order to secure an even pull along the entire distance between the down-casts. The flexible tube of the gas burner attached to the tap below, is passed through a hole (C) in the heating shelf, and all operations, other than those with a mouth blow-pipe, must be performed on the heating shelf, and thus necessarily under the hood, so that whatever fumes are evolved are sucked away. In order to compel the student to heat large vessels, such as flasks or dishes in the most favourable position, that is, well within the hood, no moveable stands are provided, but instead thereof, rings, such as are shown in the drawings. The

[4] Plate 25. This School was erected from the designs of Messrs. Mills and Murgatroyd. [5] Plate 37.

arm opposite to the ring is bent at right angles and is filed to a conical shape, so that it fits closely into a corresponding eye-hole in the brass plate, screwed on to the down-cast pipe. An opening X X, 3 inches by 2 inches, is made in either side of each down-cast, and all operations involving the sudden evolution of noxious fumes, are conducted immediately in front of this opening. When not required it is closed by a small door. Hoods of this kind have been made 12 feet long and used with most satisfactory results. A whole series may be seen at work at Finsbury Technical College. Alterations have been made, and experiments carried on to test the most efficient of several modes of actuating the draught in the main extract-shaft, which have been satisfactorily completed. A very interesting and useful addition has thus been made to chemical laboratory fittings; the whole of the hood and even the wing plates might be made of glass, but in this case the depending sides are alone glazed.[6]

3.—Draught-closets for Special Purposes.

(*a*) *Sulphuretted-hydrogen closets.* At Owen's College, small closets, 12 inches high and 85 inches in area, are provided on each bench (Plate 35); a wooden flue, 5 by 5½ inches, in the corner of the closet, connects it with the floor channel flue leading to the shaft. Each student himself prepares the gas as wanted. In most laboratories, however, a special room is provided for operations with this most unpleasant smelling gas; either a constant automatic apparatus for generating the gas is provided for common use, or it is stored in a gas holder and served by pipes to the bench or special closets—such special closets are represented in the drawing of the sulphuretted-hydrogen chamber at Leipsic (Plate 46). A series of small wooden closets is provided, all of which communicate with the main flue in the manner indicated through narrow slit openings at the back. There is a supply of the gas to each student. Two of the closets are larger than the others, and there is one for still larger operations, all being provided with gas burners for heating. A similar form of sulphuretted-hydrogen closet, at the Graz Laboratory, is shown in Plate 46. The chambers are of glazed stoneware; no fronts are provided, but these chambers are all enclosed within an ordinary large draught-closet. A somewhat more novel arrangement, at the Finsbury College, is shown in Plate 36; small copper funnels, 3½ inches wide at mouth and 4 inches high, are fixed to the flue at the top of the closet; the gas is generated in the central chamber, and thence passes to the copper tubes soldered into the sides of the funnel, a small pinch-down cock being fixed to the flue as at B. The student attaches a length of glass tubing to the copper tube by a short piece of caoutchouc tubing, or raises the flask on a stand, and then proceeds to pass the gas into the solution he is testing. All excess of gas is thus delivered directly into the flue, the connecting tube being of such length that the mouth of the vessel containing the solution is within the funnel. Any further operations with the solution, such as boiling or filtering, are also conducted in the closet, gas burners being connected with the taps, and filtering arms being hinged to the panels of the closet. Usually the student uses the closet only to pass the gas into his solution, all further operations being conducted at his bench.

[6] Professor Roscoe expresses himself in favour of draught-places for heating purposes on each bench, with down draught extract to chimney.—E. C. R.

(*b*) *Evaporation-closets.* It is customary to provide one or more evaporation-closets i.e. closets in which evaporations by steam can be conducted. These closets, however, do not materially differ from those already described, the fittings being the special part of them. Dr. Armstrong has explained to me that it is particularly desirable to have a sharp draught across the surface of the evaporating liquid, and it is to be expected that a slit opening combined with a low roof will be found of especial service in such closets. The main difficulty is to prevent condensed liquid dropping into the vessels below; and there is still ample opportunity for the exercise of ingenuity in the construction of a really efficient evaporation-closet. Probably much that is now done by steam might be more economically and satisfactorily performed by hot air; that is to say—properly regulated burners might be placed in such a situation relatively to the heated vessels that the temperature could not exceed that of boiling water. Professor Thorpe has elaborated a good example (Plate 48).

4.—Demonstration-table and Fittings.

A demonstration-table is not provided in every laboratory, but only in those where large classes have to be dealt with, as at the Finsbury College, the Manchester Grammar School, and St. Bartholomew's Hospital. It is seldom found in German laboratories, where, as a rule, the students are engaged during the greater part of their time, and get much individual attention from the teaching staff. The table should be placed so as to command the working-benches, and set upon a platform raised about 12 inches—see the Manchester, the Finsbury, and the Dundee examples. At the Grammar School, and at Dundee, the table is fitted with drawers, cupboards, and recesses, for storing the various articles which have to be issued to the students during the lesson, and is also provided with gas, water, and a sink, so that experiments can be performed upon it before the students. At Finsbury, as already explained, the space under the table is not actually used as a demonstration-table; but the balances for the junior students are placed at the one end, and the assistant has his desk at the other. In a small cupboard below is a series of wooden trays, into which bent hooks are screwed for the student's keys, a number corresponding to that on the student's bench being stencilled below each key. By thus keeping and giving out the keys at the commencement of the class, and insisting on their being returned at its close, loss is avoided, and the key-board also serves as an "attendance indicator."

5.—Lecture-room Fittings.

(*a*) *Lecture-table.* This is the most important fitting in a lecture-room, though one which does not greatly vary in form or character in different laboratories. It is and should be always a long rectangular bench, never curved nor circular on plan; its general height is about 3 feet, its breadth about 2 feet 9 inches, and as it is not desirable that one piece of apparatus should be placed before another, there is little advantage in having a wide table; as to length, there is no limit; the longer the better would be the dictum of most chemists. The table should have a hard-wood top; and now-a-days, as a matter of

course, "down draughts" must be provided, that is to say, there are openings (usually two), not less than 4 inches diameter, in the table-top, which can be closed with moveable covers, and pipes from these communicate either with the main flue, or, where there is no special system of ventilation, the pipes are carried down under the floor into a flue in the wall, where there is a gas burner to produce a draught. A portion of the table-top is often made moveable, and underneath is a large sink, which can be filled with water and used as a pneumatic trough in transferring gases, &c. This sink is sometimes glazed back and front as at Dundee. A shallow tray for operations with mercury is also sometimes constructed in a similar manner under the table-top. The space under the table should be fitted with drawers and cupboards for the store of various articles and apparatus required by the lecturer. A considerable number of gas and water taps is necessarily provided, and they are usually fixed in such positions that they can be readily got at without being in the way of apparatus. In many of the luxuriously appointed modern laboratories there are numerous other taps fitted to the lecture-table, some being for the delivery of compressed air, while others are in communication with a vacuum pump; others again furnish a supply of oxygen, and others steam. Wires from a dynamo-machine or some other source of electricity are also attached to proper terminals affixed to the table. Obviously all these special requirements can only be properly provided for when the architect is placed in direct communication with those who will have charge of the teaching; it is important that he should know of them, in order that he may not be led into the error of assuming that a mere table is all that is required. The chemical and natural philosophy lecture-tables at Dundee (Plates 42 and 43), are very complete, taken with their surroundings. The former is 20 feet long, 3 feet wide, and 3 feet 1 inch high, on a platform 12 inches high. Teak is used for the table-top and for the frames of the mercury and pneumatic trough. The front and ends are of pitch pine, and the back and framing of yellow pine.

(*b*) *Draught-closets.* One or more draught-closets are usually provided behind the lecture-table, one being of large size for the performance of experiments with large apparatus, the others being small. Where draught-closets are provided on the tables, small closets are scarcely necessary. The large closet is frequently so constructed that its working-bench is put on wheels, and thus it can be moved either into the preparation-room or into the lecture-room, as at Dundee. This arrangement renders it possible to bring forward, when required, a furnace or other piece of apparatus which it is not desirable to keep on the table during the whole of the lecture. The drawings of Dundee (Plate 41) and Finsbury Colleges are good typical examples of the treatment of wall-space in the rear of the lecture-table.

(*c*) *Other Lecture-room Fittings.* One or more blackboards, a diagram screen, a large white spring-roller blind or screen for use with the magic lantern, and a set of re-agent shelves, are all requisite fittings for the lecturer. The blackboards are frequently arranged to come down over the glazed fronts of the draught-closets; they should be suspended from large pulleys by copper-covered steel bands, to move easily. Usually they are of wood; best ground plate glass, securely mounted in a wooden frame, may be used with advantage if coated on the under side with a mixture of lamp-black and size.

For use at night, a white board is very convenient, the back of the glass being coated with ordinary white distemper. A "flashing platform" should be arranged for projecting pictures on the screen, and so placed as not to obstruct the student's view of the table. For darkening the lecture-room, revolving shutters, or special black holland blinds are usually provided, running in grooves at the sides.

6.—Preparation-room Fittings.

Here there should be a large table, on which the apparatus to be used in the coming lecture is set out, and also a working-bench for the assistant's use. Cupboards, shelves, and drawers for apparatus in constant use should be as liberally provided as possible. A number of glazed cases for the storage of apparatus and for specimens and diagrams is necessary, but these may be in an adjoining room. Space should be allowed for a carpenter's bench, lathe and vice, an anvil, a soldering bench, and a blow-pipe table. There should be a large sink and draining-table, with perforated shelving above; and near to this, if possible, there should be a large drying closet, in which glass can be placed to dry. A supply of hot water to a sink is also very useful.

7.—Store-room Fittings.

It is desirable, if possible, to have two store-rooms, one for glass and other apparatus, the other for chemicals, this being used also in making up the re-agents for students' use. The former should be liberally fitted with bins, cupboards, drawers, and shelving, solid and skeleton. The latter should be similarly provided, but should also have a working-bench for the use of the assistant in making up re-agents.

8.—Class-room Fittings.

These should be of the same kind, although not nearly so extensive, as the lecture-room fittings. The indispensable requisites are a table supplied with gas and water, one or more glazed cupboards for apparatus, chemicals and specimens, a blackboard, a diagram screen, and some arrangement for carrying off noxious fumes. For the last purpose either a down draught may be provided on the table, or a draught-closet may be constructed against the wall behind the table. If the latter, a sink may be conveniently placed within the cupboard instead of upon or near the lecture-table, and the blackboard may be arranged to fall down in front of the closet.

9.—Balance-room and Library.

The main requisite of a balance-room is a steady bench to carry the balances. To diminish vibration as much as possible, it is best to have a separate small bench for each balance, and to fix it upon brackets let into the wall. As the balance-room is frequently made use of as a reference library, a table at which students can read and write should be provided, and a cupboard for books; although, if space and funds permit, the

balances are better kept apart. A large table for use in the preparation of diagrams is an important requisite, and may conveniently find a place in the balance-room; the top ought to be moveable and adjustable to any angle, so that the draughtsman may stand in front of the board; brass scales are let in at the top and at one side, so that lines may be readily drawn at any required distance with the aid of a T-square. This table takes the centre of the room at Finsbury. On the drawings are shown the details of the benches.

10.—Assistants' Room.

In the assistants' room there should be a working-bench for their use, a draught-closet or hood, and a sink and draining-table, cupboards, drawers, and shelves should also be provided, in which special apparatus, such as measuring vessels, platinum crucibles, agate mortars, &c., continually required, may be kept, as also pure chemicals, &c., for analysis.

11.—Rooms for various Special Purposes.

The number and character of these must depend to a large extent upon local requirements, but the following are met with in all large laboratories:—

(*a*) *Gas-analysis room.* This is a room in which analyses of gases are performed; it is usually regarded as essential for its temperature to be maintained as uniform as possible and therefore the room has almost invariably a northern aspect; now, however, that it is becoming customary to make the measurements in water-jacketted tubes, this is less important than formerly. As mercury is liable to be spilt, the floor should be laid with special care; but as it is almost impossible to make a wood floor without joints, it is well to cover it with linoleum or some such material, and to fix a bead over this, so that whatever mercury is spilt may be swept into a corner and collected. At the Central Institution a cement floor is formed with a semi-circular sunk groove round to catch the quicksilver. The fittings comprise one or more mahogany-topped tables and a cupboard for storing apparatus; gas and water should be laid on, and a sink provided.

(*b*) *Spectroscope and polariscope-room.* In working with these instruments it is necessary to exclude light, and therefore to provide blinds for darkening the room; in other respects the only requisites are steady benches, a supply of gas and water, and a sink. The benches should be somewhat low, so that the observer at the instrument can be seated.

(*c*) *Photometric-room.* This room may be distinct from that last referred to, but the two are sometimes combined. It should be fitted with the requisites for testing the quality of illuminating gas, and be provided with a dark blind; in order to accommodate not only the photometer, but also a working-bench, a draught-closet, a gas-holder, &c., it should be spacious in size. A liberal supply of water and gas, as well as a sink are necessary.

(*d*) *Combustion-room.* This is a room in which gas furnaces for heating long glass tubes are placed. It is usual to provide one or more benches against the walls, with stone tops about 2 feet wide and 2 feet 9 inches above the floor level, iron hoods communicating with flues in the walls being fixed over these benches. The gas main is best fixed in front of the bench.

(*e*) *Explosion or cannon-room.* This is a room in which sealed tubes are heated in air or oil baths. The benches should be of stone, and in several laboratories the baths are placed in small open-fronted closets with stone sides and top, so that when an explosion takes place the glass may not be scattered about the room. The room should be especially ventilated and there should be an opening into the flue from each of the compartments referred to.

12.—Metallurgical Laboratory.

Here the wind, muffle and other furnaces, required for assaying and for fusion of metals, &c., are placed. The fittings are of a special character, and may be seen in laboratories like that at the School of Mines, and at King's College. Fittings of the kind may be seen at the Merchant Venturers' School, Bristol. The room should be very well ventilated into the shaft provided, and the heated air collected by a hood over the range of metal ovens and furnaces.

13.—Special Operations Room.

In every laboratory there should be one or more rooms for the performance of large operations, which cannot well be conducted upon the student's bench in the main laboratory. It is desirable that, while some of the benches in the special operations room are of the average height, others should be lower. They should be as free as possible from super-fittings. The floor should be of asphalte; and some of the benches should be of hard wood or covered with lead, while others should be of stone. A large sink and a draining-table are required, and a supply of both hot and cold water. Several large draught-closets should be ranged round the room. Steam should be laid on, and if possible motive power should be introduced into this room. Shelving and cupboards must not be omitted.

ENGINEERING OR MECHANICAL LABORATORIES.

1.—The Lecture-room.

At Finsbury this is also the physics lecture-room, with large diagram space, and a large and easily moved blackboard. It is not sufficiently well known that blackboards require to have great length horizontally. In many mathematical class-rooms they are fixed to the wall, because of the difficulty of hanging them so that they shall be easily moved. Professor James Thomson, of Glasgow, has originated a method of hanging blackboards from levers, which proves very convenient at Finsbury (Plate 51); there, a blackboard, 14 feet long and 6 feet high, can be moved up or down, through a vertical height of 6 feet, by the lecturer, who need not stop his writing as he shifts the position of the board. A separate lecture-room is necessary for the mechanical department of a college. Firstly, because the room ought to be to some extent a general mechanical laboratory, and requires special wooden beams on the walls and supports in the ceiling for carring heavy apparatus. Secondly, because students ought to be able to sit at the desks if the lecture is one of which

they have merely to take notes; and they ought also to be able to stand at the desks. Indeed, the tops of the desks ought to be constructed to rise and become more horizontal, as a lesson on practical geometry or graphical statics requires the students to stand while drawing. At Finsbury moveable tops give a broad horizontal table for students when they require to draw; these can be lifted off for ordinary lectures, and stowed underneath the fixed desks, where they create no inconvenience. It is only to every other row of desks that it is desirable to provide this moveable top, to allow passages for students between the rows of draughtsmen. In a specially arranged lecture-room this moveable top for draughtsmen who stand would sink in position, and become inclined for note-takers who sit. In all cases grooves and recesses for drawing instruments and colour saucers must be provided.

2.—General Laboratory.

The aim of the professor of engineering at a college has hitherto been that of providing one laboratory where he and a few senior students may obtain results which shall be of use to all engineers. With one exception there has been no attempt to create, and there is probably no great desire for, a general laboratory, in which *all* students at a college may make quantitative experiments during their whole study of mechanics. It is, however, the opinion of Professor Perry that there should be such a general laboratory, and although his space at the Finsbury College is quite inadequate, he has there attempted to carry out this idea. He says that there ought to be one room not less than 25 feet in breadth, and 50 feet in length, with a small room partitioned off at one end, say 25 feet by 10 feet, for students using the more delicate apparatus, and a room of about 25 feet by 15 feet partioned off at the other end. This should have a concrete floor, a sink, and high and low pressure water-supply for hydraulic experiments. The ceiling and walls ought to be crossed everywhere with timber beams sufficiently large for the fixing or hanging of machines and apparatus. A supply of small stout tables of about 3 feet high; plenty of light; the ceiling as high as possible, but not less than 15 feet.

3.—Special Laboratory.

The character of the fittings of this room which is (except at Finsbury) the only kind of mechanical laboratory usually provided at a college, depends on the nature of the researches to which the professor devotes his leisure time. A mechanical laboratory, says Professor Unwin, may be intended for researches of any kind. Testing materials for strength (iron, steel, cement for example), or testing lubricants, or testing fuels; testing the efficiency of hydrants, steam or transmissive machines; for hydraulic researches and researches on the resistance of ships, &c. Therefore the arrangement of a mechanical laboratory must depend on the particular line or lines taken up. Professor Kennedy at University College and Professor Unwin at Cooper's Hill, have constructed laboratories in which the chief work is that of testing the strength of materials. Professor Smith, of Birmingham, chiefly makes experiments on the steam-engine; Professor Huntingdon at King's College, London, devotes

his laboratory mainly to metallurgical work. That is, not only for assaying, &c., but to the composition and testing of alloys of metals with a view to the discovery of the best proportions for the various uses of brass, and other compound metals in engineering works and mineral extractions. At Cooper's Hill, the testing laboratory is 60 feet by 25 feet, with open roof and a small room for plotting results and keeping valuable apparatus. There is a hundred tons testing-machine, a lathe, slotting machine, drill, emery wheel, small forge, vice-bench, and gas-engine for driving machines. There is also a cement testing apparatus, a small lubricant tester, and some German hydraulic experimental apparatus. Professor Unwin considers the light should be northern if possible, the room should be lofty, and the shafting fixed at a good height. A travelling crane over the large machine is a great advantage. Professor Perry tells me that his students in Japan experimented with a large testing machine on numerous specimens of Japanese timber as well as on metals. They tested oils, the strength of cement on a special machine, the strength of bricks and stones with a hydraulic press. The same room also contained an engine and boiler with special fittings, to enable the efficiency of the steam-engine to be investigated. It is therefore obvious that in the matter of special laboratory fittings, the architect must consult the professor who is to be in charge of the instruction researches.[7]

4.—The Engine-room.

Where the professor of the department cannot be consulted, it is well to recollect that the engine must not only drive the workshop and other shafting of the college, but must be available for experiments also. It ought, therefore, to be high pressure and condensing with expansion valve controlled by a good governor. The room must be large so that extra tanks and pipes may be introduced. It is found that the evaporative condenser on the roof causes less water to be consumed than in the same size engine when non-condensing; as it is felt that this kind of engine will probably be largely introduced, the nature of the two large pipes for circulating pump and two for steam, going from the basement to the roof, is of some importance to the architect; it would be better that they should not be exposed to the weather. At Finsbury, where they had to be placed outside, they are emptied of water every night in the winter time. The arrangements of boiler, boiler seating, and chimney, and of the shafting to the various parts of the college, are matters in which the advice of a mechanical engineer is necessary to the architect. The shafting to various workshops, &c., must be arranged before walls are built, as metal wall boxes must be provided for.

5.—Workshops.

The fittings which concern the architect after the shafting has been put up, are the vice-benches in the iron workshop and concrete foundations for some particularly heavy tool, such as a shaping machine. The lathes will not require special foundations. The carpenter's benches are the principal fittings of the wood workshop, which also possesses a few wood-working lathes and a hand-saw. The benches not less than 4 feet apart, ought

[7] See description of the mechanical laboratories at the "Central Institution," and at the Yorkshire College, in Chapter IV.

not to be less than 3 feet wide, and ought to be provided with at least one drawer for every two students; vices of the sliding-clip pattern; plenty of space allowed round the ends of the benches. A space of not less than 12 feet square ought to be available for hand-sawing. The iron and wood workshops ought to be kept distinct, and the area of each shop ought not to be less than 1300 square feet for twenty students working at one time in one shop. At Finsbury the allowance is only about 900 square feet for twenty students, more space being greatly needed. A room for workshop stores must be provided at least 20 feet in one dimension, the other dimensions depending on the size of the workshops. This room ought to be filled with pigeon-holes, racks, and shelves. Every student ought to have a locker at least 24 inches by 15 inches, by 15 inches.

6.—Melting-room and Smithy, or Metallurgical-room.

In the basement plan (Plate 14) of Finsbury College is shown the smith's forge, with bellows worked by the shafting provided and shown. A brass furnace, brass moulder's trough, stone benches and other fittings, are required. This room belongs partly to the mechanical and partly to the chemical department, but the three furnaces belonging to the chemists or metallurgists are not shown on the drawings.

7.—The Drawing-Office.

At Finsbury the space is so limited that it has been necessary to give one common flat table to eight students, two of whom generally use it at the same time. For every twenty students using the drawing office a space of at least 1600 square feet should be provided, and the light ought to come in as much as possible to the left side of a student. It will be seen from Sir F. J. Bramwell's design (Plate 44) that no cupboards for drawing-boards or squares are required, but a set of large shallow drawers is needed for a stock of paper, finished drawings, and other stores. It is well to provide a blackboard for this room, and a set of wash-hand basins.

8.—Museum.

Professor Perry tells me that the arrangement adopted in Japan was found to be very satisfactory. A room which was probably 120 feet long and 24 feet broad, had a row of windows along one side. It had three long stout benches—two along the walls, and one along the middle of the room, and on these benches, not too close together, rested specimens of mechanism and structures, models of steam and other engines, broken specimens of iron, &c. There was no attempt to put the models one behind the other. Each was easy to get at, and there was no resting-place (except for a few exceptionally large models), except on benches all of the same height. Photographs of machinery hung on the wall fronting the windows.

Professor Kennedy of University College, London, read a paper in December, 1886, at the Institution of Civil Engineers, on "*The Use and Equipment of Engineering Laboratories*,"

which was thus summarised in the proceedings of the Institute, and published in *Industries*, and may usefully close this chapter.

"The author believed that it was essential for a young engineer to obtain his practical training, in the ordinary sense of the expression, in a workshop. But the practical training of a workshop was incomplete even on its own ground, and there appeared to be plenty of room for practical teaching such as might fairly fall within the scope of a scientific institution, and which should at the same time supplement and complete workshop experience without overlapping it. In an ordinary pupilage a young engineer did not have much opportunity of studying such things as the physical properties of the iron and steel with which he had to deal, nor the strength of those materials, nor the efficiency of the machines he used, nor the relative economy of the different types of engines, nor the evaporative power of boilers. He required such experience as might help him to determine for himself, or at least to see for himself, how other people had determined, all the principal engineering constants, from the tenacity of wrought-iron to the calorific value of coal, or the efficiency of a steam-engine, or the accuracy of an indicator-spring, or the discharge co-efficient of an orifice. He thought that this kind of practical experience could be gained best in an *Engineering Laboratory* in connection with some institution where technical instruction was given. He claimed that, in the matter of engineering laboratories, as a branch of technical education, England had really taken the lead, instead of being, as was too often the case in such matters, in the rear.

"After distinguishing between laboratories whose chief function was original investigation or research, and those whose main object was the practical education of young engineers, and after giving an outline of the method of work which he had adopted, he went on to enumerate the principal subjects upon which experiments in an engineering laboratory might be carried out, summarising them thus:—(i.) Elasticity and the strength of materials. (ii.) The economy, efficiency, and general working of prime movers, and especially of the steam-engine and boiler. (iii.) Friction. (iv.) The accuracy of the apparatus commonly used for experimentation, such as springs, indicators, dynamo-meters, gauges of various kinds, &c. (v.) The discharge over weirs and through orifices, and hydraulic experiments in general. (vi.) The theory of structures. (vii.) The form and efficiency of cutting tools. (viii.) The efficiency of machines, especially of machine tools, and of transmission-gearing. (ix.) The action and efficiency of pumps and valves. (x.) The resistance of vessels and of propellers, and experiments in general connected with both. The Paper dealt mainly with the three first subjects, the others receiving brief mention only.

"In discussing the best form of testing-machine for laboratory purposes, the author described specially the Werder machine, used by Bauschinger and largely elsewhere in engineering laboratories on the Continent, the vertical machine of Mr. J. H. Wicksteed, and the horizontal machine of Messrs. Greenwood and Batley, on Mr. Kirkaldy's principle, used by himself. Incidentally he described a number of other testing-machines, including the Emery machine at the United States Arsenal at Watertown, Fairbanks' machine, and others. The three machines first named were compared in some detail in respect to their accuracy, mode of applying load, methods of making observations, adaptability for varied

experiments, simplicity, and accessibility; and the comparative advantages and disadvantages of each were discussed, the author preferring, on the whole, the Greenwood type. The method of testing employed by the author, with pump, accumulator, and Davey motor, was then described and illustrated.

"Different apparatus for the measurement of minute extensions, compressions, &c., occurring below the limit of elasticity, were next discussed, the instruments specially mentioned being those of Professor Unwin, Professor Bauschinger, Mr. Stromeyer, and the author, as representing micrometric, optical and mechanical exaggeration of strains. Automatic test-recording apparatus was next dealt with, Professor Unwin's, Mr. Wicksteed's, Mr. Ashcroft's and the author's diagramming machines being mentioned and illustrated. Automatic diagramming apparatus for elastic strains was next discussed. The Paper contained *fac-similes* of various diagrams, both ordinary and elastic. In concluding this section of the Paper, brief references were made to machines for transverse tests, torsional tests, shearing tests, cement and wire tests, secular experiments, experiments on repeated loads, &c.

"In discussing the design of an experimental engine for laboratory purposes, the author first enumerated the principal conditions under which such an engine should be capable of working, summarising them thus:—(i.) Condensing or non-condensing. (ii.) Simple or compound. (iii.) Compound, with cranks at various angles. (iv.) With the greatest possible variation of steam-pressure. (v.) With the greatest possible variation of cut-off and other points in the steam distribution. (vi.) With the greatest possible variation of brake-power. (vii.) With considerable variation in speed. (viii.) With or without throttling. (ix.) With or without jackets, and with varying conditions as to their use. (x.) With variation of clearance-spaces. (xi.) With variation of receiver-volume. (xii.) With or without arrangements for intermediate heating. (xiii.) With variation in the reciprocating masses. He then enumerated the principal quantities which had to be measured during an engine test, making remarks upon each important point in passing. A list was given of the principal experimental engines in existence, including those in London, Birmingham, Leeds, Munich, and Liége. This section was concluded by a description of the arrangement of an experimental boiler.

"Under the head of Friction-Experiments, the principal points were summarised upon which experiments were required, in order that anything like a complete theory of friction in machines might be worked out. These included the variations of velocity, intensity of pressure, extent of contact, temperature, lubricant, method of lubrication, and nature of rubbing material. Friction-measuring machines, used or proposed by Professor Thurston, Professor R. H. Smith, Mr. Tower and himself, were briefly described. The paper concluded with a few remarks on laboratory experiments connected with hydraulic work, the theory of structures, the form and efficiency of cutting-tools, the efficiency of machines and of transmission, the action and efficiency of pumps and valves and the resistance of vessels and propellers.

"In an Appendix there were added:—(*a*) Forms used by the author for conducting engine-trials. (*b*) Notes on the principal engineering laboratories in Europe and in America, with brief accounts of the chief apparatus used in each."

CHAPTER VI.

EXAMPLES OF FITTINGS REQUIRED IN APPLIED SCIENCE BUILDINGS.

I MAY preface this chapter with a few remarks of Professor Thorpe, who devised the fittings for the chemical laboratories at Yorkshire College; he says :—" The width between the working-benches, in which the practice of designers of laboratories seems so variable, is a matter of importance. I am not aware that any other principle guided me in the special width which we adopted, than to take care that there was sufficient passage-room for a student to pass between the cupboard doors on either side when open. A great deal has been said with respect to the character of the wood of which the table-tops should be, and numerous experiments have been made. There is nothing more annoying or unsightly than either to see the wood become discoloured or see it split, as not unfrequently happens from the heat radiated from various pieces of apparatus in use. I believe Dr. Roscoe, some years since, when devising the fittings for the laboratory of Owen's College, made a number of experiments on this point, and found that, of all the woods he tried, greenheart came out the best; but I understood there was a practical limitation to its use on account of its expense.

"With regard to the question of sinks, we find, at the Yorkshire College, in the temporary sinks with which we have been working for some years, that very much less sink accommodation than that usually provided suffices us. I find, for example, that one tolerably large sink of regular shape, placed so that four men can use it at once, is all that is necessary. It seems a waste of table space and of course of money, to put up a sink for every student. We have tested that matter rather thoroughly, and I find not the slightest objection raised by the students to the arrangement now adopted.

"In most large towns the water-pressure is very considerable, and in some public laboratories care is taken to reduce the water-pressure. The high pressure has this great disadvantage, that it is almost impossible in using the taps to prevent a great deal of water being spilt about the tables; water rushes into the basins with such force that it is projected over the tables. This was got over in a very simple way by Professor Bæyer at the Munich laboratory. There the sinks, instead of being made rectangular, had oblique sides, so that when the water was shot in it struck the side inclined inwards, and was not so readily spilt over the tops.

"It was, I understood, on account of the difficulty of making stoneware sinks of that kind, that Professor Bæyer used oaken troughs, which he says in his published account of the laboratory, answer fairly well. There is one disadvantage about the use of stoneware, owing to the liability of fragile glass vessels to get broken, for of course if they strike against a hard non-yielding substance they are apt to get fractured; there is an advantage in the use of wood from that point of view. I shall try and get over that in my case, by putting at the base of the sink a very thin moveable slip of perforated india-rubber.

"Much has been said about the use of sulphuretted-hydrogen closets, and properly so, because they are very essential in the fittings of a laboratory. With respect to their working, it is an excellent system to have a large store of sulphuretted-hydrogen, but as evolved from gasometers it has this disadvantage: it is almost impossible to properly regulate the currents through the various liquids into which the gas may be passing at any one time. What I mean is that, supposing you have a very small volume of liquid of only 2 or 3 inches of depth, such an amount for example as a student engaged in qualitative analysis may have to deal with, and that you have side by side with him a student engaged in quantitative analysis, who may have large beakers full of fluid, the qualitative student gets far more than he wants and the quantitative student gets very little."

List of the examples of Fittings for Science Buildings to which attention is drawn.

PLATE

35. Owen's College, chemical students' working-tables.
36. Manchester Grammar School, ditto.
37. Finsbury College, hooded ditto.
38. Finsbury College, demonstrator's table and students' sink.
39. Merchant Venturers' School, students' working-tables.
40. Central Institution, advanced ditto.
41. University College, Dundee, chemical lecture-table.
42. University College, Dundee, working-tables and lecture-room fittings.
43. University College, Dundee, natural philosophy lecture-table.
44. Oldham Science School, working-tables; and Finsbury College, drawing and diagram-tables.
45. The College of Engineering, Yedo, Japan, details of the physical fittings.
46. Evaporating-closets and tables at Graz and Leipsic; and sulphuretted-hydrogen closets at Graz.
47. Hofmann's evaporating-closets, Bonn and Berlin.
48. The evaporation, draught, and sulphuretted-hydrogen closets, Yorkshire College.
49. Experimental dyeing tables, Yorkshire College.
50. Finsbury College, private laboratory draught-closets.
51. Professor James Thomson's lever blackboard.
52. The North London Collegiate School, chemical laboratory.

Owen's College Fittings. *Plate* 35

Contains details of the students' operation-benches of the chemical laboratory of *Owen's College, Manchester.*

Fig. 1 is a half elevation of the quantitative students' operation-benches. They are double benches for four students, each with sinks at the ends only and draught-closets in the centre, with re-agent racks over, and closets and drawers under.

Fig. 2 is part of the elevation of the qualitative students' operation-benches, less width being allowed to each student. They are double benches for ten students with eight basins on the tables and ten draught-closets.

Fig. 3 is an end elevation of the qualitative tables.

Fig. 4 is a plan of one of the qualitative tables, showing the table and re-agent rack-tops; a sectional plan through the re-agent racks shows sliding glazed doors through the closets under table-tops, and through the draught-closets, and central division.

Fig. 5 is a cross section through the re-agent racks, the draught-closets, showing extract-shaft, and the tables, drawers, and shelves, &c.

This example is interesting, because it illustrates the table fittings of the first really efficient chemical laboratory erected in this country, which combined all the latest improvements up to date, in the fittings and general arrangement of the rooms and system of ventilation. Sir Henry Roscoe published an illustrated account of it, and it has greatly influenced all subsequent efforts in this country.

Manchester Grammar School Fittings. *Plate* 36

Contains details of the students' operation-benches at the chemical laboratory of the *Manchester Grammar School*, and a section through the sulphuretted-hydrogen closet at *Finsbury College, London.* The latter illustration shows the curved metal roof and rising sashes, and the V-shaped extract-flue extending along the top, with a lower aperture to take away the fumes in filling the bottle *in situ* on a three-legged stand; the arrows show the direction in which the fumes are drawn by the action of the extracting fan. The arm of the supply-pipe and its valve B are also shown.

Fig. 1 shows a front elevation of one and a half places, with and without the lower closet doors.

Fig. 2 is a longitudinal section through the drawers and shelves, table-top, sink, and tube slides.

Fig 3 is a cross section through the benches and draught-closets over same, showing the withdrawal of the fumes of the coupled closets by a single flue, and the position of gas and water supply-pipes.

Fig. 4 is a cross section through the bench basins and re-agent racks, showing the position of the basins and the mode by which they conduct the waste water to the **V** lead-lined trough-gutter which empties into a receiver connected with the horizontal and vertical drains. The section of the horizontal extract-flue and the toe space under bench-bottom is also clearly shown.

Fig 5 is a part plan of the table-top, showing the positions of the sinks, the twin draught-closets, the re-agent racks, &c., and taken in connection with the sections it makes the matter clear.

Fig. 6 is a section through the lecturer's bench, showing cupboards, front and back, drawers, and end re-agent racks.

These fittings and the general arrangements of the laboratory in which they are situated, and the admirable manner in which they are ventilated and drained and supplied with gas and water, &c., &c., have been very generally approved, and afford an excellent example except for one thing, and that is, that it is generally recognised as more suitable to place the tables at right angles to the windows when they occupy the body of the room, as at Munich, Zurich, Owen's College, the Yorkshire College, the Merchant Venturers' School, &c., &c.

Finsbury College Fittings. Plate 37

Contains details of the students' operation-benches at the chemical laboratory of Finsbury Technical College, London. The fittings were designed by Dr. Armstrong, and are well worthy of study. Fig. 1 is a plan of one of the tables taken at the level of the re-agent racks, which in this case occupy the centre of the table-top, with a wide shelf over, and at the level of the operation-shelf which extends the whole length of the table, and is covered by a glazed hood from which the fumes are drawn away as they collect, by the four vertical flues. There are no fume-closets required on the tables by this hood arrangement, and the sinks are situated at each end of the tables. The table-tops and the sinks are covered with lead. The filtering arms, the ring brackets round flues, the sink strainers, &c., are all clearly shown.

Fig. 2 is an end elevation, showing the glazed hood end and metal flue supporting it, the sink and waste therefrom, the water supply to the two pillars over it, and the gas supply.

Fig. 3 is an elevation of the whole side of one of the tables, which taken in connection with the cross section, (Fig. 4) is a very graphic illustration of the principle adopted. The apex of the inclined sides of the roof of the hood is cut off, or rather enclosed, by a horizontal piece of metal, leaving about an inch on each side open for the entrance of the fumes. This horizontal plate is attached to the head of the extract-flue, which is 4 inches square, and may be raised or lowered to regulate the size of the opening into the extract-flue. This flue is of metal and pitched inside, and descends to the horizontal flue in the floor leading to the chamber at one end of the laboratory, where there is a 2-foot Blackman's fan, which is turned by the machinery connected with the engine in the basement, and so draws out and sends upwards the noxious fumes collected from all the tables.

Fig. 4 shows an operation going on in a flask in a tripod with gas jets underneath on the operation-shelf under the hood. It also shows the re-agent bottles *in situ*. The slides for the filtering arms are shown in the small detail.

This is an original suggestion, and has proved successful.

Plate 38

Contains details of the demonstrator's table and students' sink in large chemical laboratory at Finsbury College.

Fig. 1 is a half plan of the demonstrator's platform and table and students' sink. Fig. 2 is a section through same, showing the hinged teak table-top—beneath which is the long cistern—from the lower part of which the supply taps are fixed over the student's sink, which has a perforated false bottom for strainer. Fig. 3 is an elevation of both, showing the nine service-taps over the lead-lined sink. Dr. Armstrong prefers this plan for junior students, to that of providing basins on the tables.

Merchant Venturers' School, Bristol. Plate 39

Contains details of the students' operating-benches, worked out by the author from the sketches of the head-master, Mr. Thomas Coomber. Their peculiarity lies in the largeness of the draught-closets on the tables, the lifting shutters for enclosing re-agents, the waste cupboard over the sinks, of which there are two to eight students, and the mode of extracting the fumes. Fig. 1 is an elevation of half the bench intended for eight students' use, representing two places, with three drawers and three cupboards beneath, one of which is for the reception of the re-agent shutters. Figs. 8 and 9 give details in elevation and plan of the said shutters when occupying the cupboards. The draught-closets, three in number, are shown one at each end, and the other in centre with the closed re-agent racks and sinks between. Fig. 2 is a cross section through the re-agent racks and drawers and cupboards under, showing toe space and the V-shaped open waste-water channel of wood pitched inside. Fig. 3 is a cross section through the basins and extract-shaft and the closet over basins. Fig. 4 is a longitudinal section through the tables, showing the arrangement of the extract-flues, and the increasing depth of the horizontal shaft as each vertical shaft debouches into it. The course of the waste-water channel is shown and its inclination towards the receiver, the overflow of which passes into the drains of stoneware laid in lead-lined troughs in floor; the section cuts through the re-agent shelves and draught-closets and basins. And Fig. 5 gives the part of the end elevation, wherein is the door giving access to the space between the drawers and cupboards. Fig 6 is a half plan of the table taken below the teak table-top. Fig. 7 is a half plan taken above the table-top, and is sufficiently explanatory without further description.

The Central Technical Institution, London. Plate 40

Contains details of the advanced students' operating-benches in the chemical laboratory. Dr. Armstrong, the professor of chemistry at the Central Institution, South Kensington, was formerly the professor at Finsbury College, and upon him fell the chief labour of devising the fittings for that college. On his advancement to the Central Institution, his first duty was to work out the details of the equipment of his department; Professors Ayrton, Unwin, and Henrici, being employed on their departments of physics, mechanics,

and mathematics, while the director and secretary, Sir Philip Magnus, designed what was required for the administrative department. Mr. Waterhouse carried out in detail the suggestions of his many masters, and the result is highly satisfactory, in spite of the fact that the consideration of the fittings of this building was not fully effected prior to the general construction, so that much unnecessary expense was entailed to overcome the peculiarities of the construction, some of which must ever remain to be regretted, viz., the ironwork used in the construction of the physical department by which the electric currents are disturbed. It was one of the advantages which resulted from the professors being appointed before the original plans were arranged at the Yorkshire College, that ironwork was prohibited in the construction of this part, and even the steam-chests of the heating apparatus were excluded.

But the illustration given in Plate 40 is another example of Dr. Armstrong's great ingenuity. At Dundee College, the operation-tables at Owen's College were copied exactly (compare Plate 35 with plate 41). But although Dr. Armstrong had struck out an original plan for the tables at Finsbury College (see plate 37), he was not satisfied to repeat his own invention, but conceived the present fittings, which differ from others in the large size of the draught-closets and their duplicate construction; the arrangement of the re-agent shelves at right angles to the length of the tables, three shelves being attached to each side of the coupled draught-closets, thus leaving the whole of the tables between the draught-closet open and free. In these tables for eight advanced students a draught-closet and a sink is given to each, so that each is responsible for the use he makes of his own fittings.

Fig. 1 gives a half elevation of one of these tables, showing the draught-closets and re-agent shelves above the table, with the holes for passing the arms of filter brackets —a simple device of great practical value (see end elevation, Fig. 2). Under the tables are drawers and cupboards, and a hinged flap giving access to the long glass tube slides beneath which is a sloping roofed recess for a rubbish pail. Fig. 3 gives a cross section through the draught-closet and central divisional extract-flue, extending the whole width and forming a slightly sloping back to the closets on each side of it. These sloping divisions are within an inch of each other at the top, and 4 inches at the bottom, opening into a horizontal extract-flue about 15 inches square. A detail of the apex of the glazed roof, showing the mode by which the backs forming extract flues impinge and come short in height by 1 inch from the roof is given in Fig. 4.

The draught-closet is, however, not a draught-closet in the usual interpretation of the words, but is only a glazed hood arrangement like that which extends the whole length of the tables at Finsbury: the backs of the re-agent shelves forming the sides of the hooded closet, the depending vertical front panels of which are hinged to turn upwards as desired. The extension of a narrow slit the whole width of a draught-closet is a distinct improvement, since the force of the draught is not appreciable till within a short distance of the aperture, therefore the more widely distributed the aperture, without increasing the area, the better. These divisional backs have been made in wood, in iron, and in glass.

Fig. 5 is a longitudinal section through the table, which will now be clearly

understood. The section is taken between the back plates forming the horizontal extract-shaft, and through the apex of the hood over. It also shows the cupboard shelves, at the end of each of which are two horizontal tube slides, the cross section of which is given in Fig. 7. Toe space is provided under the cupboards as shown in all the sections and elevations.

Fig. 6 is a cross section through the table, showing the sinks in section and the extract-flue and the sloping tube slides and rubbish-pail recess under them, the re-agent shelves appearing over the table-top. Fig. 9 is another cross section, taken through the drawers and cupboards and sliding doors to same. Fig. 8 is a half plan of the table looking down on the finished hood-roofs in the case of the central hoods; and in the case of the end hoods the plan is taken at the level of the table-top, showing extract-flue and re-agent backs in section, and the bead stop on the open side in elevation. The arrangement of the skeleton framing and the positions of the sinks are clearly defined.

This is an extremely interesting and suggestive example, for it should be understood that the details given in this book are not presented for absolute and exact imitation, but to show the varied ways in which the same ends may be attained, and to offer suggestions for still better and simpler combinations. It is in the direction of greater simplicity that design always runs when the principles and objects are clearly apprehended.

University College, Dundee. Plate 41

Contains a ground plan of the new chemical laboratory of the University College, Dundee (Fig. 3), and at a glance it will be perceived that it is a very close imitation of Professor Roscoe's laboratory at Owen's College, even to the wall dividing the quantitative and qualitative laboratories, which is now thought to be a useless isolation, increasing the difficulties of general supervision. With this exception the plan is an admirable one, and because the system of ventilation is said to work well (though I have not personally visited the building or tested the apparatus), I have given a full description of it with woodcut illustrations in the eighth chapter of this volume.

The rest of the details on this sheet are devoted to the illustration of the chemical lecture-table. On reference to the plan it will be seen that the lecture-room has a preparation-room immediately behind the lecturer, which is admirably situated between the lecture-theatre and the museum of specimens and apparatus; a smaller lecture-room being also in direct communication with the museum. Perhaps there is no better subject for a young architect's study than buildings of this class, because his whole mind must be given to the uses of every corner of it, and his artistic powers must be exercised in giving a fitting form to arrangements fixed as fate.

Fig. 1 gives the back elevation of the lecture-table, showing the drawers, cupboards, and recesses, and draw-out sink. The fronts are of pitch pine and the top is of teak.

Fig. 2 is a cross section through the draw-out sink, showing flap and waste and cupboard. Fig. 4 is the elevation of the table next the auditory, which is also fitted with drawers and closets. At one end is a pneumatic trough with hexagonal glazed front; at the other is a glazed mercury trough with closet under. The sections through each of these are given in Figs. 5 and 7, while Fig. 6 gives a plan of the table-top, showing the relative positions of the parts in dotted lines, the gas and water services and down draughts, and the hinged leaves at each end.

Plate 42

Contains the details of the working-benches at Dundee, which, as already observed, are similar to those of Owen's College (see Figs. 3, 4, 7, 8); but, as before mentioned, the division wall between the lecture-room and the preparation-room is well used, and is typical of the kind of fittings, variously arranged, required in such a position in science lecture-rooms. Figs. 5 and 6 give plans of the said wall at different levels, and are taken through the draught-closets on either side, and the vitiated air-flue therefrom, in front of which the blackboard is hung with lines and weights as a sash. The central opening has a glazed sash on either side, and forms a chamber in the thickness of the wall. A sliding board is added on the preparation-room side, and a blackboard on the lecture-room side, in front of which again there are diagram-suspending screens or frames, as shown in the section (Fig. 1) and in the half elevation (Fig. 2). In the section is shown the slate-topped table, which occupies the opening and is placed on wheels which run in grooves, and enable the table to be drawn into the preparation-room to receive its apparatus, and then to be drawn into the space in the rear of the lecture-table at pleasure.

Professor Weinhold, at Chemnitz, has a portion of his lecture-table so fitted that the apparatus may be passed from the large lecture-room to the small lecture-room without removing it from the table upon which it was first arranged.

Different professors have different habits and customs, and some attach no importance to this convenience. It will be observed in this instance that the lecturer is raised on a platform, and this platform extends into the preparation-room as far as is needed to receive the intermediate table.

In Fig. 2 the half elevation of this end of the lecture-room is clearly displayed, and the positions of the diagram frames and the blackboards above referred to. It also gives the form of the roof of the laboratory and the pulleys for raising and lowering the frames, &c.

Plate 43

Contains the details of the lecture-table in the natural philosophy and mathematics department at Dundee.

Fig. 1 is an elevation of the front towards the auditory, showing the nests of drawers and the central portion, which folds outwards to show a glass tank. Fig. 2 gives the end elevation; Fig. 3 the back or lecturer's side of the table, showing the

drawers and the central recess to get at the four gas jets which are used to illumine the long water-tank.

There are also two slate tanks, one at each end of the table, and Fig. 4 is a section through one of these, showing cover to lift, traps for gas, and drawers. Fig. 6 is a section through the centre of the table on the side next drawers, showing the long water-tank and hinged flap in front of same. Fig. 5 is a plan of the table, showing the traps for gas, for water and exhaustion, the tank covers, and the electric wire covers.

In the body of the book, notably in the description of the Liverpool laboratory, I have given other professors' ideas of an efficient table for lecture purposes, but these illustrations are sufficient to indicate the necessity for a thoughtful consideration of the construction of such fittings.

Oldham Science School and Finsbury College Fittings. Plate 44

Contains details of the Oldham Science School chemical laboratory working-tables (Figs. 4, 5, and 6), and these are interesting, not only because they are parts of a skilfully and economically arranged laboratory (given in plate 26 of the previous chapter), but because of their own peculiarities. Figs. 4 and 5 show a transverse section and half-front elevation of the double tables occupying the centre of the room, and it will be observed that a novelty appears in the provision of a seat on a cast-iron turning bracket, and a desk takes the place of one of the drawers, and when outdrawn increases the area of table accommodation, and enables the student to keep his notes and books clear of the working table-top. This provision of a seat for tired evening students is a great boon. There is an apparatus-drawer and a refuse-drawer in front of the basin or sink, which is lined with lead, and the table-top is grooved radially a few inches round the sink opening with a slight fall to basin. Sliding doors are provided for the cupboards under and toe space is allowed. The re-agent shelves extend the whole length of the tables, interrupted only by the draught-closets which extend the whole height. The gas and water supplies are shown, and are extremely simple but quite efficient.

Fig. 6 shows the adaptation of the benches to the walls. The windows are high up for the most part, and do not interfere with the re-agent shelves between the draught-closets, through which the section is taken.

Finsbury College drawing and diagram-tables.—Figs. 1 and 2 illustrate Sir Frederick Bramwell's drawing-table, which provides not only a plan drawer, but a drawing-board rack, with side door to pass in and out the boards between the racks provided ; only half of the table's width being thus occupied, space is left for the knees and feet. The top is extended laterally 6 inches on one side and 13 inches on the other ; above this is a second moveable table-top, sustained on wrought-iron rising uprights secured to the under side of top, which can be raised or lowered at pleasure to any angle, by reason of the hinge to the front uprights, the stops being by pegs or racket arrangement.

Fig. 3 is a sectional detail of a diagram-board ; the grooved, slotted, and braced board being twice the width of its skeleton frame and boarded support (forming cupboard), is

hinged to quadrants, enabling the table-top to be turned up to any angle to be within reach.

The College of Engineering, Yedo, Japan. Plate 45.

The physical department of this Imperial College was fitted up by the architect from the sketches and instructions of Professor Ayrton, F.R.S., the present professor of physics at the Central Institution, who was promoted from a similar professorship at the Finsbury College, to which latter college he was appointed shortly after his return from Japan, where both Professors Ayrton and Perry had for many years been engaged by the Imperial Government of Japan.

Fig. 1 is the ground plan of the physical laboratory. *Room No.* 1 is the demonstration-room, 50 feet square, and occupying the whole height of this portion of the building. It is fitted up in the following manner:—On a level with the first floor, a gallery about 3 feet wide runs round the whole room, from which wires and other apparatus are suspended for experiments, it also gives access to shutters by which the upper windows can be closed to darken the room for optical and other experiments.

The students' benches occupy the centre and three sides of the room; next the walls, on the ground floor level, are instrument and working-cases; the under side of the gallery being utilised for cupboards entered from behind.

Room No. 2 is the general laboratory, fitted with instrument-cases, covered-in working-tables, the tables being on concrete foundations; and uncovered instrument-tables on brick piers. *No.* 3 is the professor's private room and laboratory. *No.* 4 is the instrument-room. *Nos.* 5 *and* 6 are for electrical experiments, *No.* 5 being fitted up with six brick pillars, each about 2 feet square and descending 6 feet into the ground. *No.* 6 has long tables on brick piers. *No.* 7 is the lavatory attached to the laboratory for washing bottles, &c. *No.* 8 is a small artificially-drying room, in which experiments with frictional electricity can be conveniently performed.

On the first floor, which extends over all but the demonstration-room, are rooms for experiments on light, a small class-room for the teaching of applied physics, rooms for special experiments, store-closets, and the battery-room. This battery-room is fitted for about 200 Grove's cells and 300 Daniells', used for general electrical work and for the electrical testing of the students of telegraph engineering. The peculiarity of these special fittings is that all the cells are under glazed covers, and therefore dust is excluded; yet all the cells are visible, and all obnoxious gases are led up the flues; the cells are easily got at by opening any portion of the double-hinged cover.

When taking a Grove's battery apart, after use, the zincs are put at once into the long narrow leaden sink immediately in front of the battery stand, and the porous cells are put on the racks to dry, and are ready for use within reach of the operator putting up the battery on the next occasion.

Of Professor Ayrton's drawings I have seen ten, and out of these I have chosen a few representative examples.

Demonstration-room Fittings. (*Figs.* 2 *to* 9.)

The sloping platform or students' gallery is shown on Plate 45, both back and side elevations, and in the side sectional view, Fig. 14. I have indicated by dotted lines the brick piers which sustain the students' tables, distinct from the general flooring, so as to be free from the room vibration. There are also front, back, and top views of the students' benches. Figs. 15, 17, and 19, with sinks, gas and water supplies. Figs. 18 and 20 are cross sections through the tables, No. 20 being through one of the sinks; and Fig. 16 is an end elevation; all of them show the brick piers upon which they stand. By a special arrangement of students' benches (which was unique of its kind at the period of its adoption), it is possible for the students without leaving their places to repeat the experiments made by the professor during the lecture, with apparatus placed ready for them on these firm benches. Between the lectures these benches or tables can be utilised as part of the laboratory proper.

Instrument-cases with folding doors and glazed panels are arranged around a portion of the demonstration-room, and are also used in the laboratory. The professor's lecture-table also rests on a platform, the whole being sustained on a concrete foundation distinct from the general flooring, and its fittings include a pneumatic trough sink.

Laboratory Fittings.

Illustrations are given of the working-tables in glass cases (Figs. 2, 3, and 4), furnished with rising sashes, as used in the general laboratory and in the professor's private laboratory.

The tables in the cases rest on a concrete foundation quite distinct from the flooring of the room, to avoid the transmission of vibrations; so that even when the sash is closed after work—to exclude dust or meddling fingers—no part of the case rests on the table, there being no connection between the table carrying the apparatus and the floor, on which rest the sash frames and glazed enclosure, and before which the experimenter stands. With such working-cases a delicate investigation can be carried on from day to day, the apparatus being always ready whenever the experimenter has leisure to work it. Some of the working-tables for less delicate operations have no concrete bases (Figs. 8 and 9). Instrument-cases are provided with casement sashes (Figs. 5, 6, and 7), and with rising sashes (Figs. 10, 11, and 12).

I may remark, by the way, that the fittings of the physical department at Yedo were contrived to enable students to learn by advancing the bounds of knowledge, and not by merely assimilating existing information, as is evidenced by numerous published accounts of original research conducted in that laboratory; and it is this method of teaching which has given to Professor Ayrton the "prestige" which he enjoys, and which he has carried with him to the Central Institution of the City and Guilds of London Institute for the Advancement of Technical Education.

The Universities at Graz and Leipsic. Plate 46

Contains three perspective sketches. A view of the students' operating-benches at Leipsic, and of Kolbe's sulphuretted-hydrogen closets at the same University chemical

laboratory, also Professor von Pebal's porcelain sulphuretted-hydrogen closets at Graz. Both Pebal and Kolbe adopt a vertical slit opening for the extract-flue, see Figs. 1, 2, and 3. Kolbe's range is shown to be in the corner of a room ; the wall-flue in the return wall is shown in the plan (Fig. 3), with the relative positions of the closets, with sloping backs towards the slits, the back flue, and the upcast.

The following is a translation of Professor von Pebal's description of the sulphuretted-hydrogen room at Graz. He says : "Between the operation-rooms is a glazed space, fitted with doors, inside of which are two draught-places, which can be closed by rising sash windows, and in these the sulphuretted-hydrogen apparatus is placed. In these draught-places are niches of glazed earthenware, similar to the wooden niches in the laboratory of Professor Kolbe at Leipsic. These are open to the front, and at the back have narrow openings in connection with the horizontal canal, and through this with the chimney ; above each of these niches stands a small wash-apparatus, mainly for the purpose of noting if a sulphuretted-hydrogen cock has been inadvertently left open.

"In addition to the sulphuretted-hydrogen cock at the disposal of each student, is a second cock which can only be turned by a special key, and which is so placed that only a very slow stream of sulphuretted-hydrogen can pass through the wash-apparatus. Since it is in many cases necessary to treat warm liquids with sulphuretted-hydrogen, at the bottom of each niche is a large round hole in which a 'flame cooler' can be placed ; on this rests an earthenware plate, which can be heated by means of a gas lamp placed under the table. Since large vessels cannot stand in these niches, in the second draught-place the niches are done away with, and the canal leading to the flue is covered with a straight wall of tiles, with long vertical slits to take off the sulphuretted hydrogen. The sulphuretted hydrogen is prepared in a draught-place in a room in the basement, and is conducted through a leaden tube to the sulphuretted-hydrogen room placed directly above."

The design of the Leipsic working-table (Fig. 4) is sufficiently obvious by the sketch given ; it may be interesting to give a translation of Pebal's description of those provided by him for the University of Graz. He says : "The working-tables are made of deal and provided with oak tops, each has three drawers (one of which goes through the whole depth of the table, to hold long glass tubes), and a cupboard underneath.

"In constructing the fittings, I insisted upon the re-agent cupboards being supplied with locks, to insure the re-agents being kept clean and pure. The usual methods of locking up were either inconvenient or too complicated, and thus easily got out of order. The simple method I adopted obviated these drawbacks. The glass fronts, which run on rollers in a groove, can be drawn out sideways and pushed behind or between the cupboards through a slit prepared to receive them.

"As the re-agents in the lock-up cupboards would be injured by fumes of hydrochloric acid, nitric acid, ammonia and sulphate of ammonia, the bottles containing these substances are placed on shelves, lined with white glazed china or tiles, situated in the middle division of the re-agent cupboards.

"Two 'Arzberger-Zullowsky' hydraulic air-pumps and the barometers belonging to them, are placed on each side of the re-agent shelves. Two of these air-pumps have the tubes attached to them on the table itself. White glazed earthenware vessels are placed

under the waste basins for the reception of used filter-paper and the like, which should not be thrown into the sinks."

The general arrangement of the laboratory at Graz, in which these tables are placed, appears to be thus:—Around each of the eight cast-iron pillars which support the roof, are placed four double working-tables. One of the ten windows is widened out into a large recess (after the pattern of the laboratory at Pesth) for the reception of a small lecture-table. Working-tables are also placed in the remaining nine windows; accordingly the laboratory contains forty-one places besides four draught-places next the corner windows. At each pier is a small "Hofmann's working-niche," the sides next the windows being arranged for lock-up re-agent shelves for the window working-tables.

The opposite blank walls of the laboratory are used for the reception of four small draught-places for the evaporation of acids and the like. Between every two, steam-drying closets are fastened to the walls. Two of the draught-places contain small steam-baths; the two others, evaporating apparatus heated by gas.

The Bonn and Berlin Universities. Plate 47.

The illustration here given of the draught-closet designed by Hofmann for the chemical laboratories of the two Universities of Bonn and Berlin, in 1866, is a typical example; indeed, it was the only detail given in the appendix to the Report on the chemical laboratories then in course of erection at Bonn, made by Professor Hofmann, to the English committee of council on education.

The professor gives the following description under the head of "*Evaporation niches.*" "In a great number of chemical operations vapours detrimental to health are evolved, which should be removed as quickly as possible from the working-rooms. To effect this, every laboratory is provided with a few large places ventilated by chimneys in which such work is conducted. In the case of the Bonn laboratories there have been constructed, instead of one or two *larger* niches, a considerable number of smaller ones distributed over the entire space, so as to enable the manipulator to perform such operations almost without leaving his bench. For this purpose nearly all the window piers are provided with niches.

"The essential conditions which an arrangement of this kind should satisfy, are the following:—

"1. A speedy and certain withdrawal of obnoxious gases.

"2. Supply of air to support combustion.

"3. Protection of the liquids to be evaporated from condensation products deposited in the flue.

"4. Continuous removal of these condensation products, and of liquids that may be spilt in the niche, &c.

"In the construction of these niches, no materials are to be employed which would be acted upon by such vapours.

"At Bonn the niches are arranged along the outer walls of the building in the spaces between the windows; they project somewhat from the inner face of the wall, in no case, however, so far as to impede the passage round the benches.

"Each niche consists of an open space having an area 20 inches square, and a height of 26 inches—dimensions generally sufficient for the reception of the apparatus usually employed.

"The bench of the niche is 3 feet 2 inches above the floor of the laboratory: a height selected for all tables, window-sills, niches, &c. The base, the sides, the back, and the roof of the niche are made of compact sandstone; the opening in front is closed by a pane of plate glass, which can be adjusted in any position by means of counterpoises acting over pulleys. Fig. 1 shows the elevation; Figs. 2 and 3, plans of the niche above and below the level of the working-bench; Fig. 4, the vertical section.

"For the removal of vapours the funnel-shaped roof communicates with an earthenware pipe, 7 inches in internal diameter, rising within the wall to a height of 21 feet 6 inches from the floor.

"A gas flame burns in the funnel to promote the draught; the gas issues from a steatite burner which is cemented into a porcelain pipe entering from the side, and by this means the employment of metal, which would be rapidly corroded, is entirely avoided. The gas pipe, on account of its fragility, is so placed that it can be easily removed.

"To protect the liquids evaporating in the niches as much as possible from any dirt that may fall down the flue, the latter is not situated directly over the gas flame, but lies nearly a foot deeper in the wall. The connection between the niche and the flue is effected by a Y-joint of glazed earthenware, the form and position of which are apparent from the section, Fig. 4.

"The upper opening of this joint is intended for the reception of the flue; the two lower ones, branching out, close the aperture in the roof; whilst the other, lying in the prolongation of the flue, fits into a second funnel pointing downwards and likewise set in the roof of the niche. Here collect all the products deposited in the flue, which are washed down its walls either by rain or condensed water; the liquid comes down on the side next the niche, being likewise directed into the funnel by means of a semicircular, sharp-edged rim, projected from the interior surface of the Y-joint near its upper extremity. From the funnel the products run down to the base of the niche through a small leaden pipe let into the wall behind it.

"The bottom stone of the niche, into which the products fall, has a shallow basin form; and a perforated slate slab lies over it to make a horizontal surface. Liquids, accidentally spilt or otherwise, pass through a small lead pipe into a moveable box lined with lead, which is also a receptacle for used filters, &c. To prevent air entering the niche through the waste pipe, the lower end is bent upwards so as to form an air-trap.

"It will further be noticed that the outer air is introduced into the closet by a curved pipe connected with a flat horseshoe-formed channel, with two apertures giving admission to the closet; plate glass lids are provided.

"The object of this arrangement is to prevent a return current or down draught in any of the flues."

The Yorkshire College, Leeds. Plate 48

Contains details of the fittings of the above College, designed by Professor Thorpe.

The *sulphuretted-hydrogen draught-closet*, (see Figs. 1 to 4), in the sulphuretted-hydrogen room, differs from the foreign types already described, and is simply a single glazed chamber with slate bottom on iron brackets, with a trapped sink at one end, and two extract-flues. A plan, elevation, and section are given, with a detail section through the meeting rails of the lower rising and the upper fixed sashes. Greenwood's friction slides are used.

The *evaporation-niches* are very simple, and said to be very effective (see Figs. 5 to 8). The five porcelain pans have five separate compartments, with glazed sashes in front fitted with Greenwood's friction slides; a sloping opaque glass roof and glazed divisions, with descending flag-lined flues into the flag-covered horizontal flue sustained on stone bearers. The walls are lined with tiles.

A wooden shelf on brackets sustains the sash frames, &c. The pans may be heated by steam or gas at pleasure, in the manner shown.

On the subject of evaporating apparatus, Professor von Pebal makes some useful remarks in his description of the fittings for Graz laboratory, of which the following is a translation:—

"The arrangements commonly in use for boiling and evaporating (especially acids) appeared to me to need improvement. Water-baths, sand-baths, protecting plates, wire-gauze, various metallic objects, as well as gas-lamps, are soon destroyed by the agency of vapours, or at least are very difficult to keep clean. The large shallow sand-baths commonly used have many disadvantages, and it is difficult to regulate their temperature, so that substances shall not spurt out from the vessels into neighbouring ones, because only a small portion of the surfaces of large vessels with convex bottoms can be exposed to the heat. Beginners in analysis generally take too much acid, ammonia, and the like, and have to evaporate the surplus afterwards; and they also allow fluids to boil over, thereby besprinkling the surroundings, and often cannot be prevented in time from performing such operations on their working-tables. The objects are, therefore,—

"1. To construct an arrangement by which vapours cannot come into contact with metal.

"2. To apply this arrangement in such a way as to induce the students, through its convenience, to evaporate such substances in the specially appointed places only."

His remarks on steam-baths, apparatus for evaporating over gas-lamps with "flame coolers," and on evaporation niches, are all very thoughtfully considered and fully illustrated in his book.

The intermediate *wall draught and hot-closet*, behind the lecture-table, between the physical lecture-room and its preparation-room, is given in Figs. 9 to 13. Section B., Fig. 13, shows how a white screen is let down over the blackboard on the side of the draught-closet in question for magic-lantern exhibits, and is worthy of observation. The draught-

closet itself has a blackboard hung with balance-weights (see elevation and section). The glazed enclosure of the closet both rises and falls in the manner shown. The chamber walls are lined with tiles, with glass shutters to the flues. An iron tray sand-bath forms the bottom of the closet, under which are the gas jets forming the hot-closet, which has a slate bottom and a Doulton's sink and water supply. There are flues for both the hot-chamber and the draught-closet over it (see Section A. and the upper and lower plan, Fig. 10). This is altogether a very complete example of its kind, and works well.

The *chemical laboratory draught-closets.*—These are as simple and inexpensive as can be. A stone slab roof to flue and bottom shelf of closet, which stands out as a projecting glazed cabinet from the wall, about 3 feet from the ground, in the manner shown in Figs. 14, 15, and 16, with details of construction given in Figs. 17 to 23.

The Yorkshire College. Experimental tables in Dye-House, &c. Plate 49

Contains complete details of the fittings of the working-tables and the lecture-tables (Figs. 1 to 13).

The apparatus required for experimental dyeing is a water or steam-bath, or oil or glycerine-bath heated with gas or steam, provided with a perforated cover for the reception of the dye-vessels, which serves for the simultaneous and equable heating of the latter. The dye-vessels themselves should be of toughened glass or well-glazed porcelain, and capable of holding about half a litre or even one litre. So says Professor Hummel in the second edition of his work on the "Dyeing of Textile Fabrics," and on page 483 he gives a plan and end elevation of a very convenient arrangement for experimental dyeing, made by Messrs. Broadbent and Sons of Huddersfield. It is the same apparatus as that fixed in the end of the lecture-table at the Yorkshire College dye-house (Figs. 7 to 13). The experimental working-tables (Figs. 1 to 6) are each fitted with ten sets of six pans each set, to each of the tables, and cost somewhere about 200*l.* a table. The plans, sections, and elevations given will make clear the following description extracted from Professor Hummel's admirable manual.

"It consists of a couple of strong cast-iron pipes or cylinders into which iron cups for holding glycerine are screwed. The porcelain dye-vessels rest in the glycerine cups, and are clamped down by means of a flange protected with indiarubber or asbestos rings. The cylinders are so supported that they may readily turn on their axes by means of the handles, for the purpose of emptying the dye-vessels without leaving the bench. The axes are hollow and serve respectively for the introduction of steam at one end, and the escape of condensed water at the other."

The steam is at fifty to sixty pounds' pressure, and simultaneously raises the temperature of the water in the series of porcelain dye-vessels to boiling point. Under each pan and cylinder apparatus is a trough sink, with wastes therefrom to drain, clearly shown in the longitudinal and transverse sections through the table.

The gas, water, and steam-pipes are arranged as shown. At Huddersfield the cylinders are not hung on pivots at each end but are fixed, and the porcelain pans have to be taken off the tables to be emptied.

Finsbury College private laboratory Draught-closet. Plate 50

Contains the details of the private chemical laboratory draught-closet designed by Dr. Armstrong, and intended for use (as in this case) where there is no connection with the extracting flues usually provided and actuated by a fan or furnace (see Figs. 1, 2, and 3). A slightly sloping glass back (see plan and section) extends the whole width of the closet, which has two moveable divisions. This back is about an inch from the wall at the top, and as the fumes rise in the chamber they are drawn away, behind the glass, to the horizontal extract-flue just under the closet; one end of which communicates with the wall flue, at the base of which is the ring of gas jets actuating the current upwards in the upcast-flue (see plan and wall section next the elevation of the front).

The two side compartments have a metal roof half the height of the central part. Greenwood's slides are used for the teak sashes, and a "squeege" presses against the glass of the rising sash, so that no air escapes except by the proper extract-flues. This has answered perfectly, and is, in fact, the common way of arranging for the withdrawal of fumes when there is no general system of extraction available.

Professor James Thomson's Blackboard. Plate 51

Contains the details of this very perfect arrangement, which has been fitted up at Finsbury College lecture-room, and is so sensitive to movement that it may be moved up and down with the little finger, although the blackboard itself measures 14 feet wide by 6 feet 6 inches high (see Figs. 1 to 7).

The elevation (Fig. 1) shows the board with its skeleton framing, suspended by chains to the arms of two levers, from the opposite ends of which depends the counter-weight (both board and weight moving in guides). The plan and section and details of construction are all given, and certainly, I know of nothing more entirely successful; it is easy to enclose the levers with a screen with pilasters and cornice, if it is desired to hide the mechanism, which, however, is not attempted at Finsbury, where it performs the useful purpose of showing how its success is achieved and is a mechanical lesson in itself.

Professor Perry, who is the professor of mechanical engineering at Finsbury College, and who is in daily use of the blackboard above referred to, thus describes the principle of Professor James Thomson :—

"It is absolutely necessary that the lecturer should not rub out a mathematical formula until the end of the lesson, and this requires a very long blackboard, the longer the better. As one who has to teach mathematics, I should say that a blackboard ought not to be less in length than 30 feet. A long blackboard is usually fixed to the wall. You can write, perhaps, at 6 feet from the ground to 3 feet, but it saves much mental worry to be able to write all formulas at about 5 feet from the ground. It is, therefore,

of importance to move the whole of the blackboard up and down with a touch of the finger, as Professor James Thomson's arrangement enables you to do; instead of doing what might suggest itself at once to everybody—hanging the blackboard by two chains over four pulleys, and having a very heavy balance-weight for the whole board, which involves a most tremendous amount of friction—we hang the ends of the well-framed board by two chains from the long arms of two levers; the shorter arms of these carry a heavier balance-weight, and the only places where friction can occur are the fulcrums of the levers. This allows a very large motion of the board for a small motion of the balance-weight, and is exceedingly convenient. When these fulcrums are slightly oiled, a touch of the chalk at any part of the board is sufficient to lift the blackboard."

The New Chemical Laboratory at the North London Collegiate School for Girls, Sandall Road. (*Plate* 52.)

This laboratory was completed from the designs and under the superintendence of the author in the year 1885, and is given as an illustration of what is a sufficient provision for high schools for the middle classes of both sexes, where there is no special system of ventilation and where moderate cost is an object.

The illustration (Figs. 1 and 2) gives a longitudinal section and plan of the room, which measures 30 feet by 20 feet, and averages 16 feet high. Provision is made for twenty-four students' working-places in three double tables with a central and two end sinks of porcelain. An Argand gas burner on a pillar is situated in the centre over the re-agent shelves dividing each of the tables longitudinally, which not only gives light to the room, but also accelerates the current of air in a shaft for the extraction of the products of combustion immediately over it. This shaft has two arms, at the extremity of each of which is a hood, under which all operations causing bad odours are carried on. In the ceiling is an escape for the air of the room generally, by a jacket pipe surrounding the heated flue fume-extractor (see detail of benches and extract-shafts therefrom Fig. 4).

There are no draught-closets on the benches, they are superseded by the hoods described; but two large draught-closets are provided with extract-flues, actuated by gas jets (see Figs. 7, 8, 9, and 10); three store-closets for chemicals and apparatus and glass tubes, &c., also one large sink and straining board.

The fittings are of pitch pine with teak tops to the tables. After the full description given of other working-tables, and the completeness of the details here shown, it is unnecessary to make any further remarks, except to say that they have proved successful in practice.

In addition to those already described, there are also wall ventilators actuated by a "Bunsen" burner gas jet, for the general ventilation of the room.

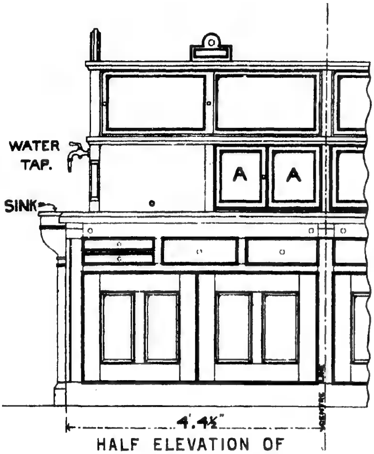
Four vertical shafts at the corners of the room admit fresh air, which may be increased to any extent by opening the windows.

The room is warmed by two open fireplaces, fitted with Boyd's school-board stoves, into which fresh air is passed from without through a grating in front of the stove, and is thus slightly warmed in its passage when the fire is alight. The chimney flue is of course another mode of vitiated air extraction. This plan may be termed an example of natural ventilation, the fire and gas jets simply acting as aids to the current, which exists at a lower velocity without them.

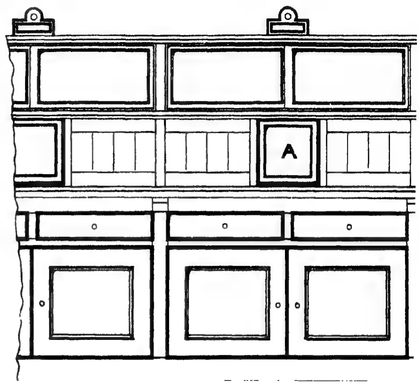
There are several more of the author's buildings to which he has been required to add chemical laboratories, such as Milton Mount College, Gravesend, and Caterham Congregational School, both boarding-schools for between 150 and 200 students—and day-schools, such as Sandall Road School and Camden School.

OWEN'S

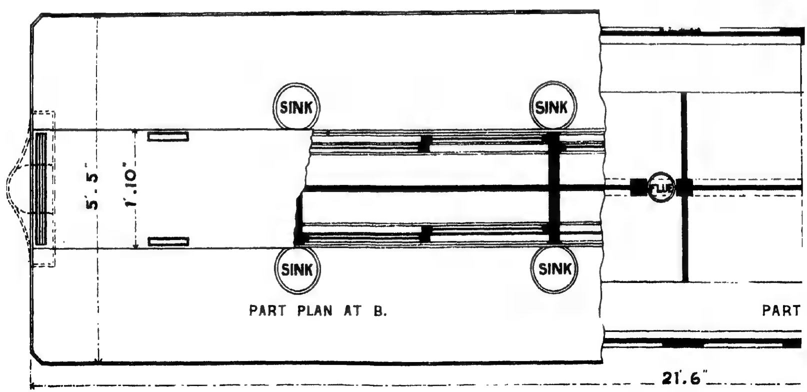
STUDENTS' W



HALF ELEVATION OF
QUANTITATIVE TABLE
FIG. 1.



PART FRONT EL

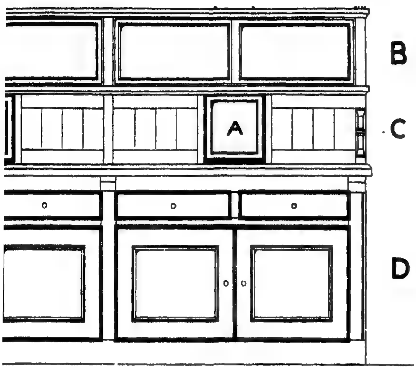


PLAN OF QUALITATIVE TABL
FIG. 4.

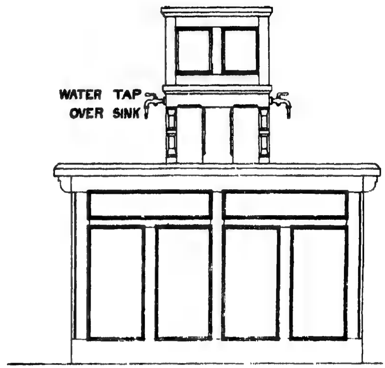
INCHES 12

ANCHESTER.

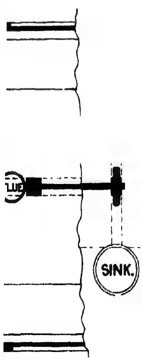
EMICAL LABORATORY.

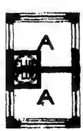


LITATIVE TABLE.

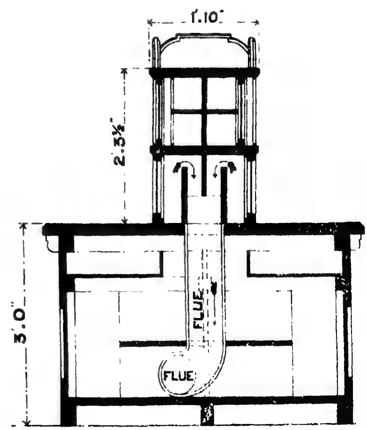


END ELEVATION.
FIG. 3.

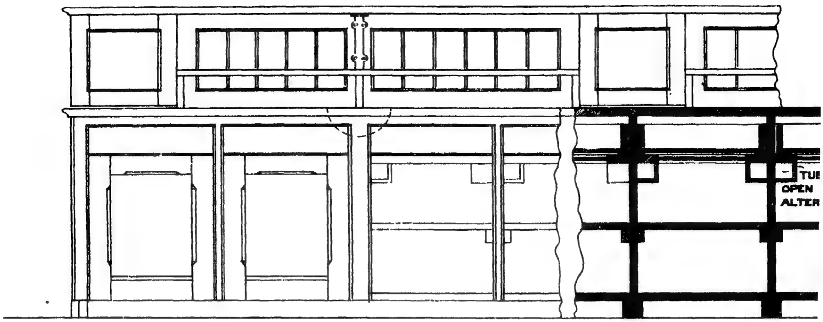




PART PLAN AT C.

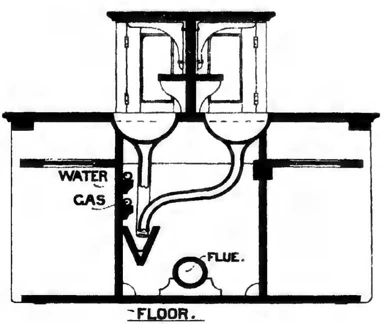


SECTION THRO. TABLE
FIG. 5.

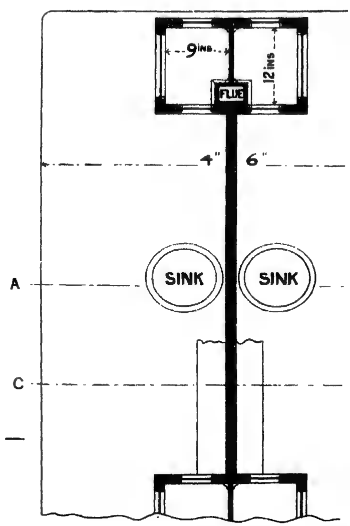


ELEVATION.
FIG. I

SECTION.
FIG. 2.



SECTION ON LINE A.B.
FIG. 4.

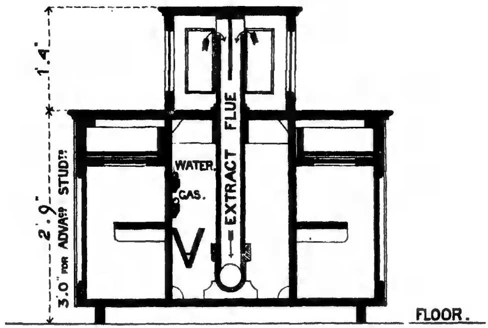


PART PLAN OF TAB
FIG. 5.

INCHES 12 0 1 2

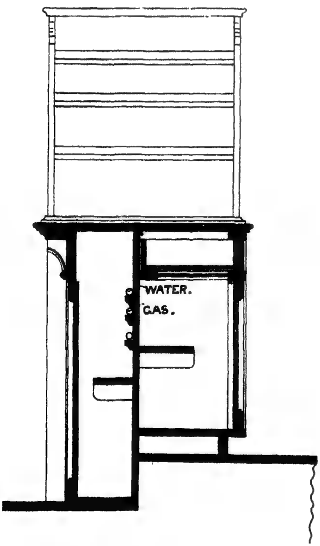
SCHOOL.
LABORATORY.

PLATE 36.

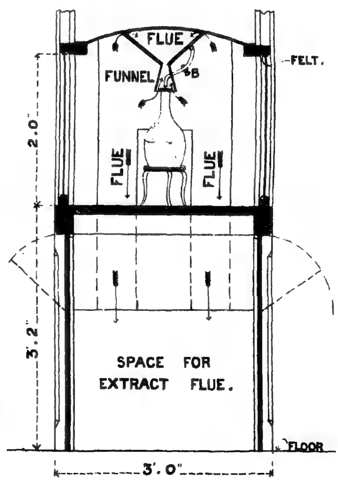


SECTION ON LINE C.D.
FIG. 3.

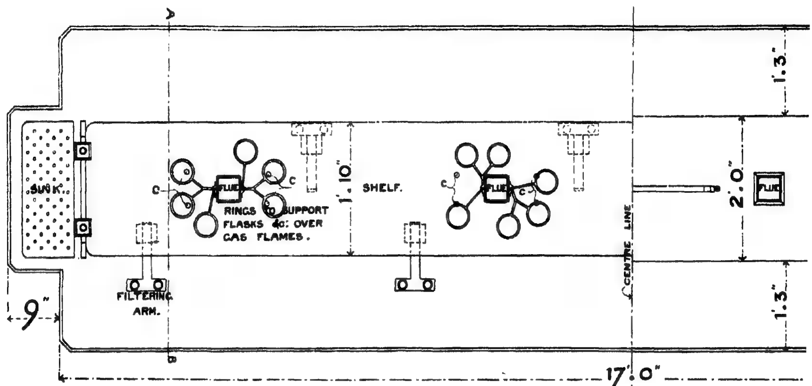
FINSBURY TECHNICAL COLLEGE.



SECTION THRO.
LECTURERS TABLE.
FIG. 6.

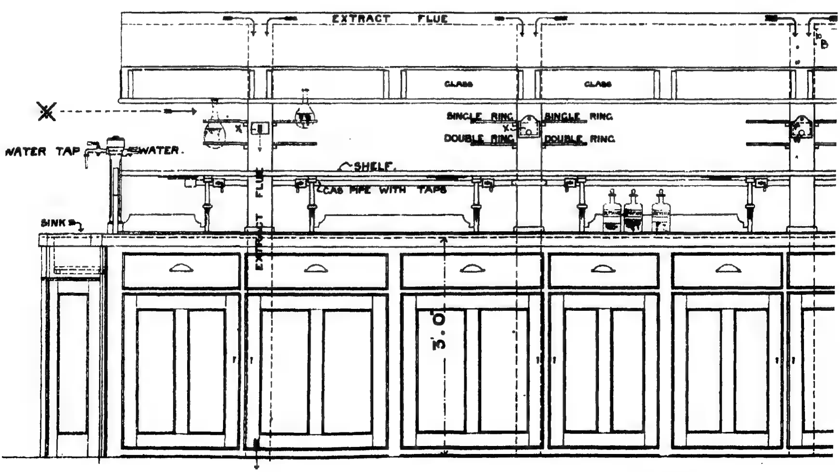


SECTION THRO: SULPHURETTED.
HYDROGEN DRAUGHT CLOSET.
FIG. 7.



HALF PLAN AT LEVEL X.

FIG. I.

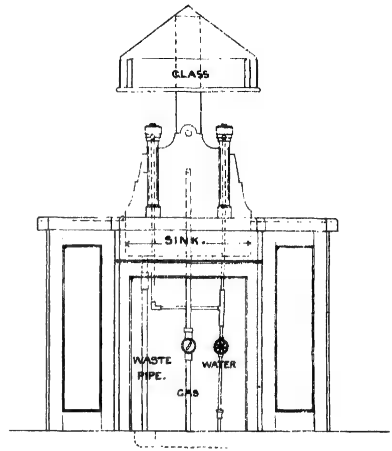


ELEVATION.
FIG. 3.

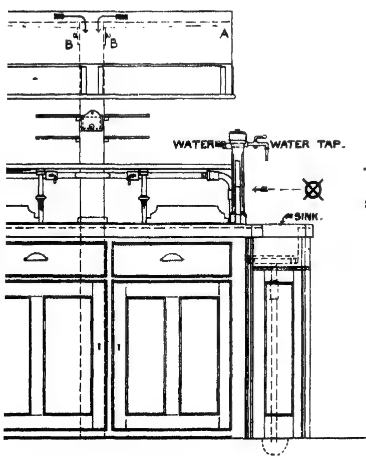
COLLEGE.

:AL LABORATORY.

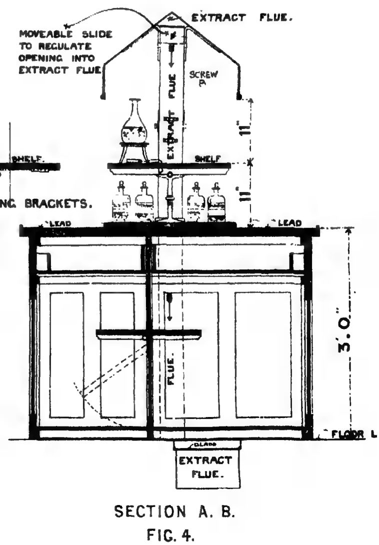
.EVEL M.



ELEVATION AT O.
FIG. 2.



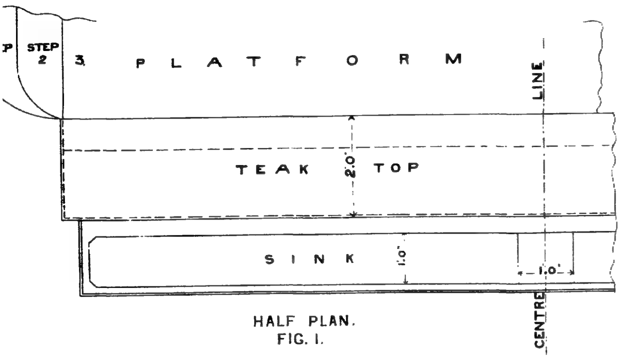
SHEWING SLIDING BRACKETS.



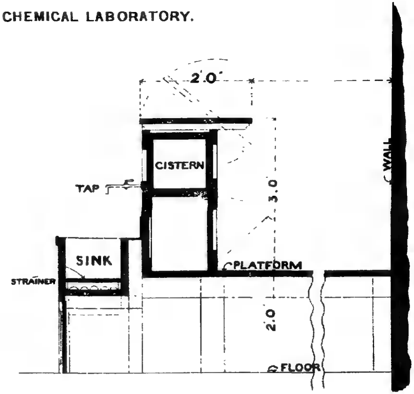
SECTION A. B.
FIG. 4.

FINSBURY TECHNICAL COLLEGE.

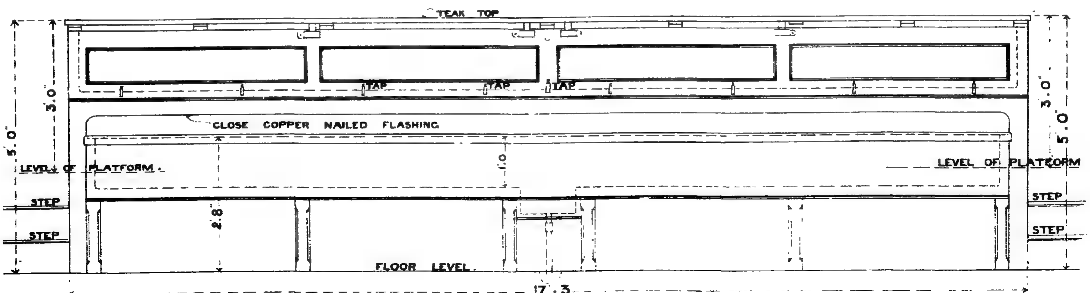
DEMONSTRATION TABLE AND STUDENTS' SINK IN CHEMICAL LABORATORY.



HALF PLAN.
FIG. I.



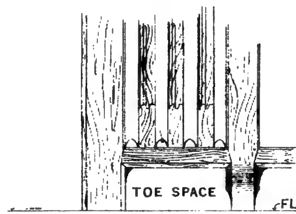
SECTION.
FIG. 2.



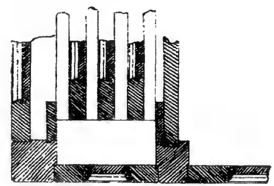
ELEVATION FIG. 3.

MERCHANT VENTURERS' SCHOOL, BRISTOL.

STUDENTS' SMALL WORKING TABLES.

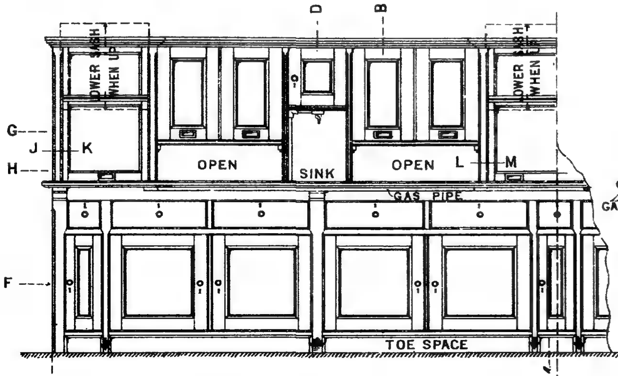


PART ELEVATION. FIG. 8.

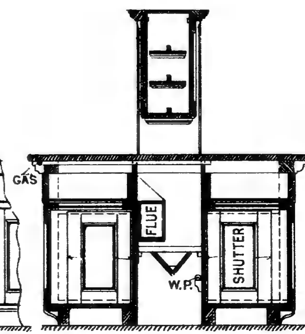


PLAN THRO'. SHUTTERS'. FIG. 9.

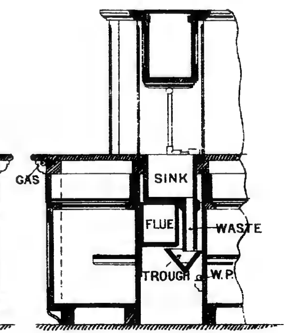
DETAILS OF SHUTTERS' CUPBOARD.



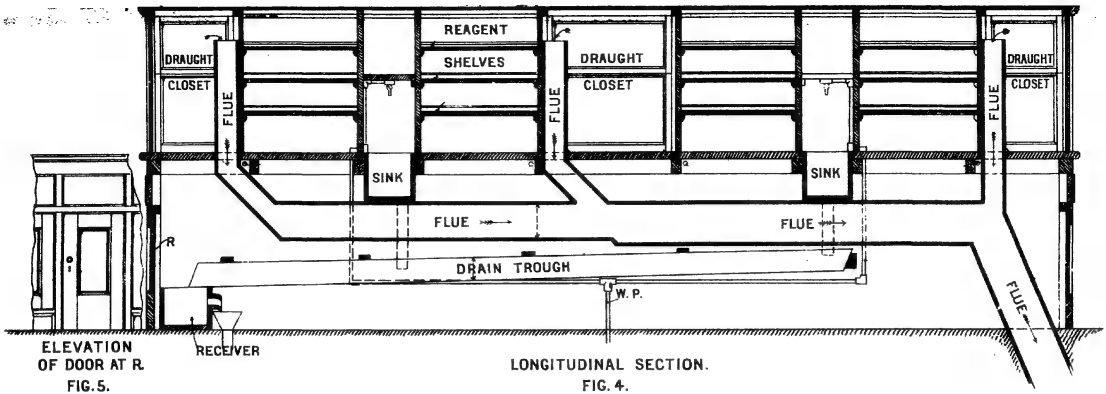
HALF FRONT ELEVATION.
FIG. I.



SECTION. A. B.
FIG. 2.



SECTION. C. D.
FIG. 3.



ELEVATION OF DOOR AT R.
FIG. 5.

LONGITUDINAL SECTION.
FIG. 4.

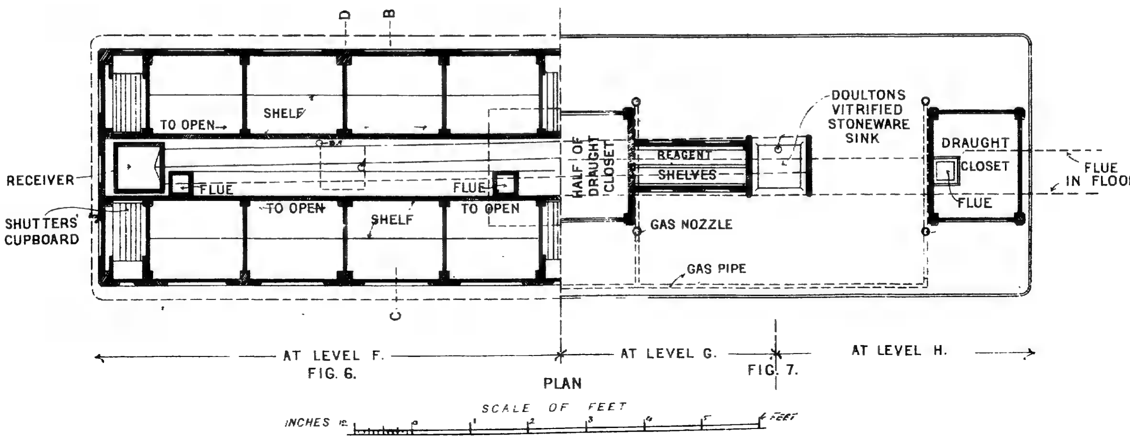


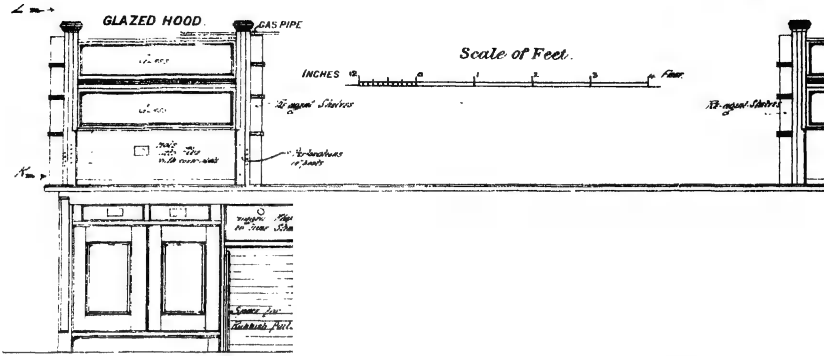
FIG. 6.

FIG. 7.

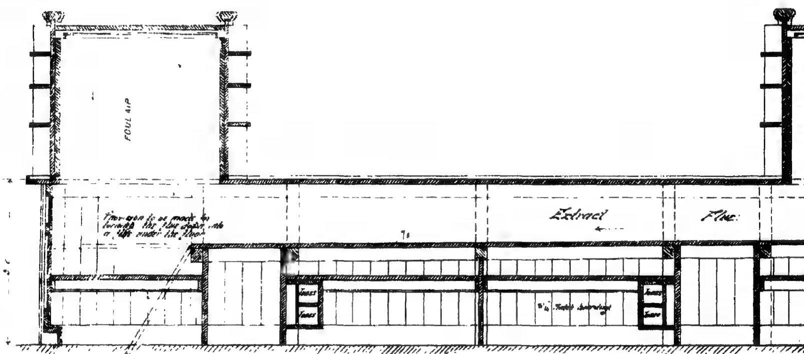
PLAN

THE CENTRAL INSTITUTI(

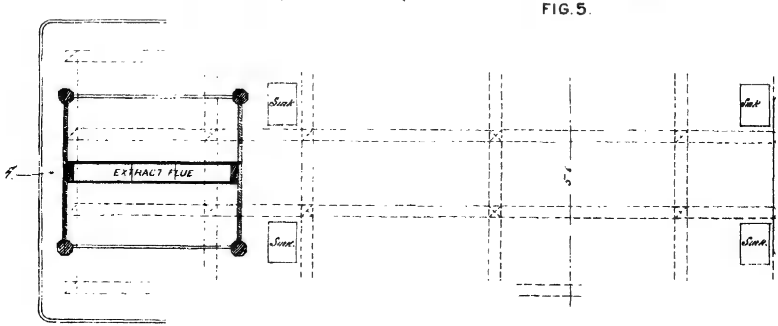
WORKING TABLE IN (



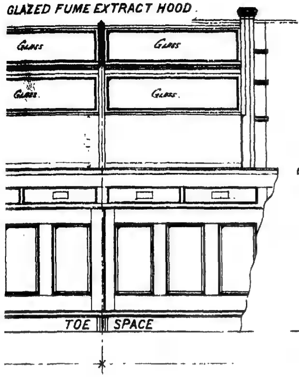
HALF OF SIDE ELEVATION
FIG. I.

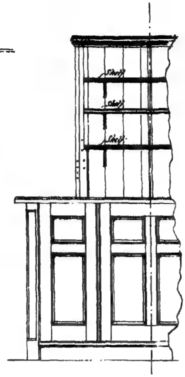


HALF SECTION A.B.
FIG. 5.

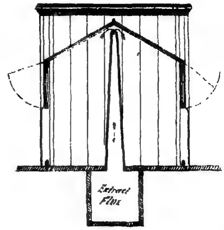


GLAZED FUME EXTRACT HOOD.





HALF END ELEVATION.
FIG. 2.



CROSS SECTION OF GLAZED HOOD
FIG. 3.

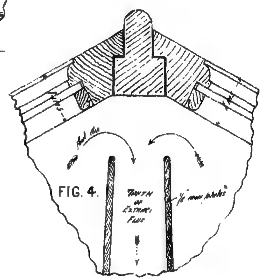
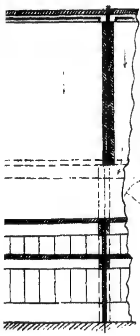
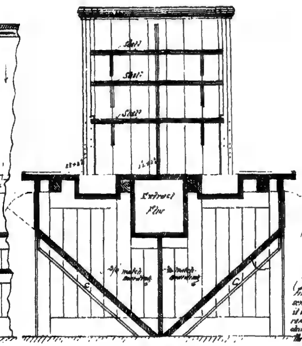
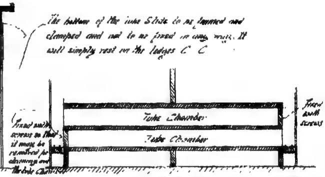


FIG. 4.

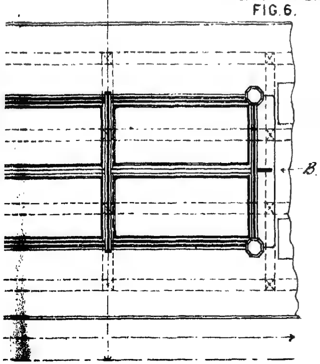


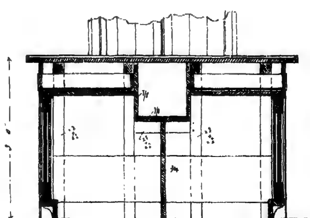


SECTION D.E
FIG. 6.



SECTION THRO' TUBE CHAMBERS FOR EXTRA LONG TUBES
FIG. 7





SECTION E F.
FIG. 9.

UNIVERSITY COLLEGE DU

DETAILS OF LECTURE

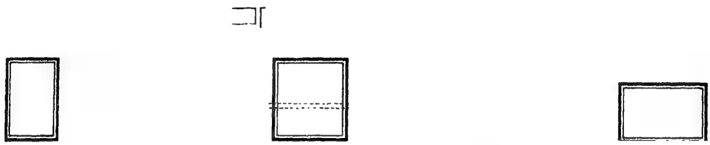


FIG. 1. BACK ELEVATION. PITCH PINE FRONTS.

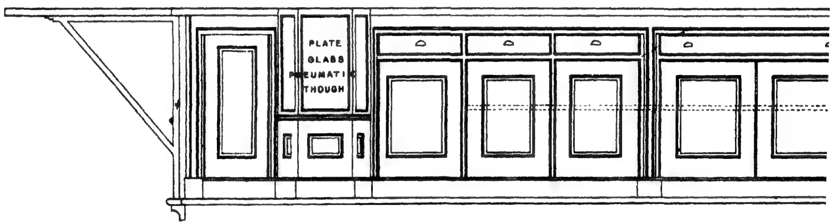


FIG. 4. FRONT ELEVATION

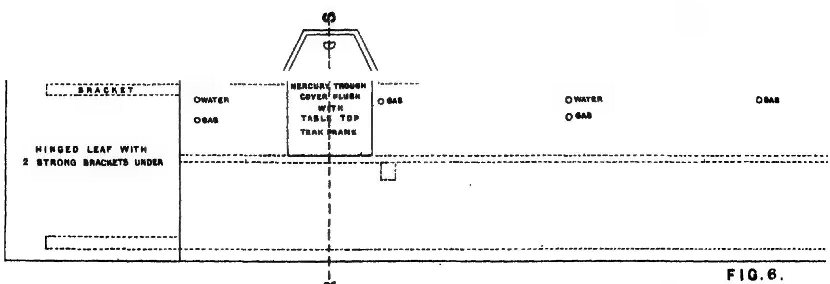
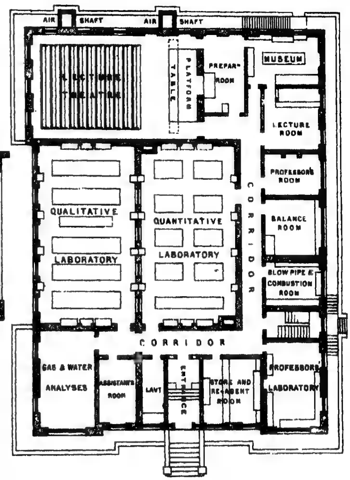


FIG. 6.
PLAN OF TABLE

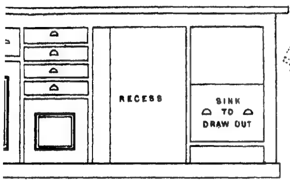
FIG.3.

SKETCH PLAN OF UNIVERSITY COLLEGE, DUNDEE.



DEE. CHEMICAL LABORATORY.

ABLE IN LECTURE THEATRE.



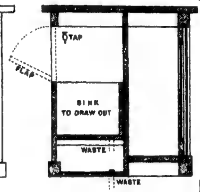
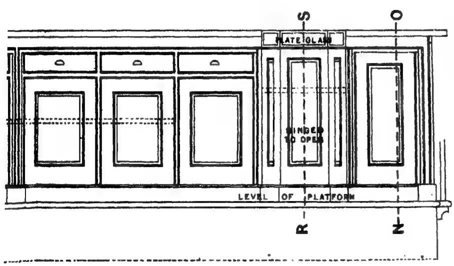


FIG.2. SECTION N.O.



PITCH PINE FRONTS.

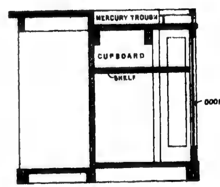
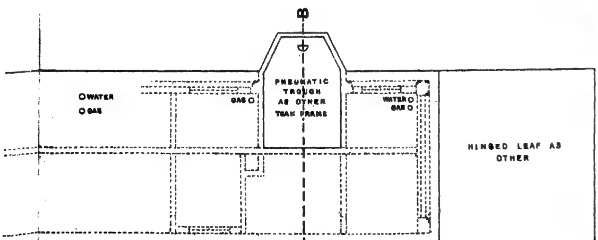


FIG. 5

SECTION R.S.



DOTTED LINES SHOW FRAMING BENEATH.

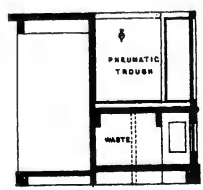
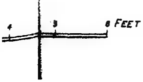


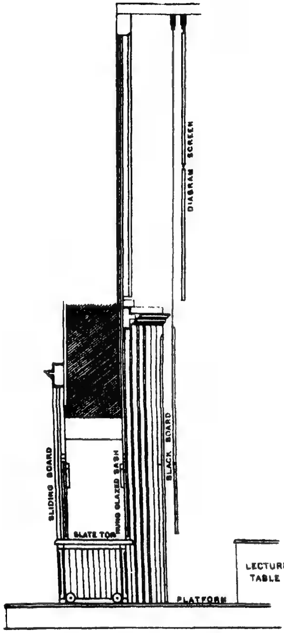
FIG. 7.

SECTION A.B.

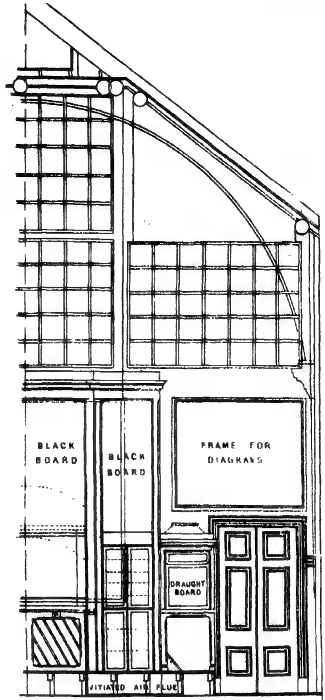
P FORMED OF TEAK.



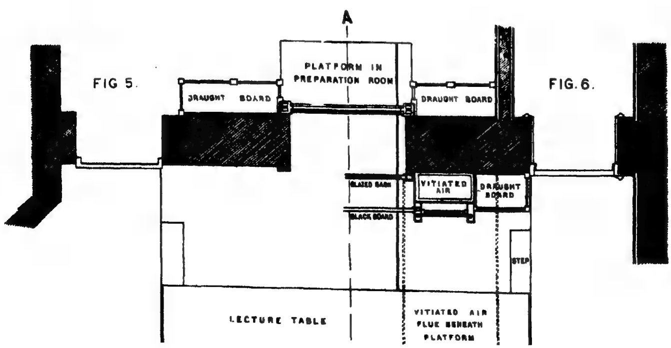
UNIVERSITY COLLEGE DU

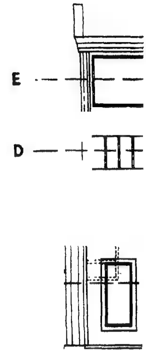


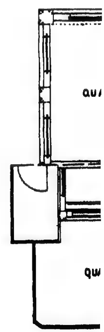
SECTION THRO A.B.
FIG. 1.



HALF ELEVATION OF LECTURE ROOM.
FIG. 2.







)EE. CHEMICAL LABORATORY.

STUDENTS WORKING TABLES.

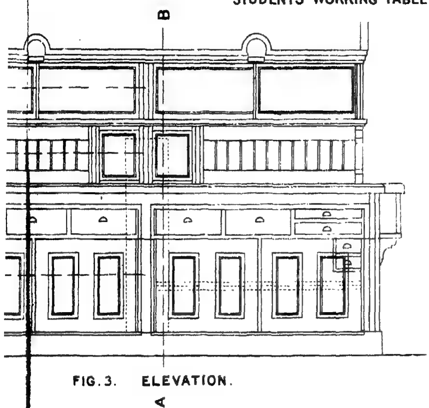


FIG. 3. ELEVATION.

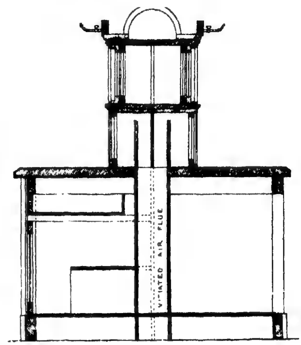


FIG. 4.
SECTION ON A.B.

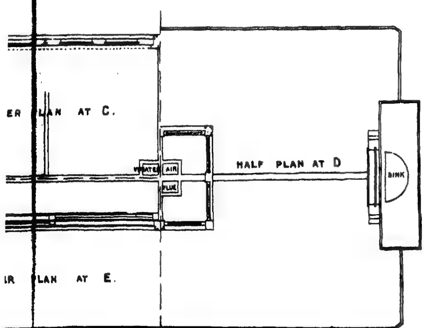


FIG. 7. PLAN

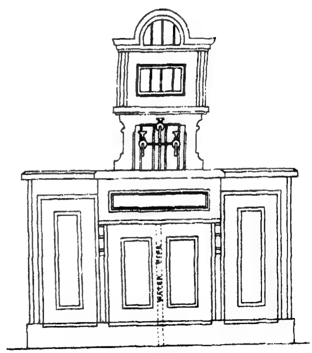


FIG. 8.
END ELEVATION OF SAME.

UNIVERSITY COLL

NATURAL PHILOSOPHY AND MATHEMATI

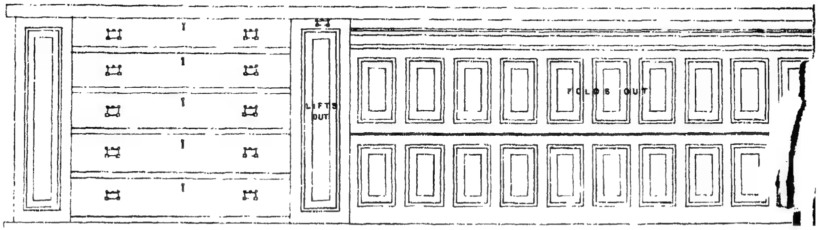


FIG. I FRONT OF TABLE.

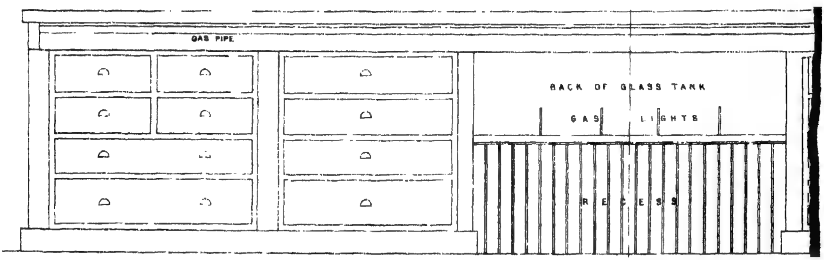


FIG. 3. BACK OF TABLE.

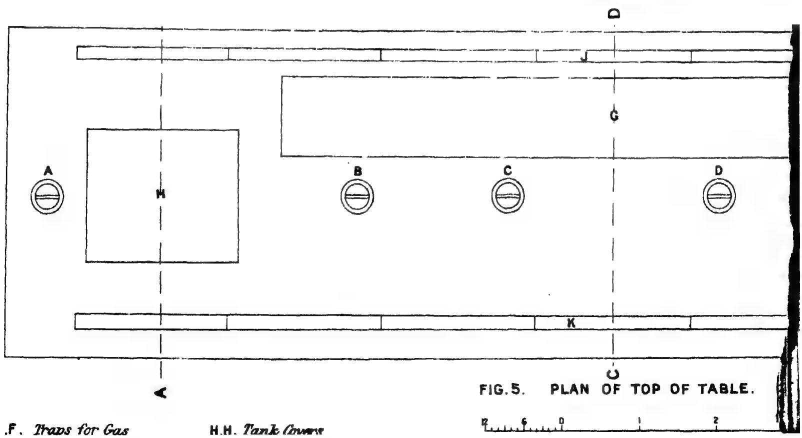


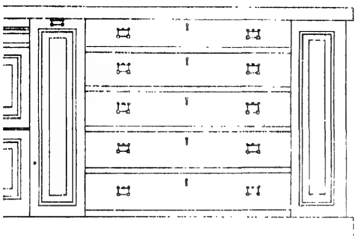
FIG. 5. PLAN OF TOP OF TABLE.

.F. *Traps for Gas* H.H. *Tank Covers*
C. *do* , *Water* J.K. *Electric Wire Cover*
D. *do* , *Exhaustion* G. *Large Tank Cover*

PLATE 43.

DUNDEE,

§ DEPT LECTURE ROOM TABLE .



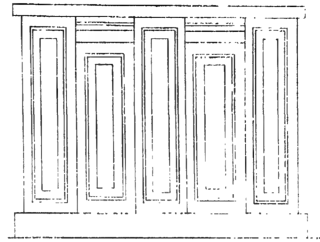
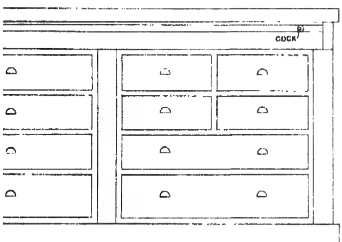


FIG 2. END



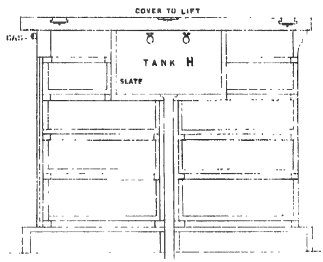
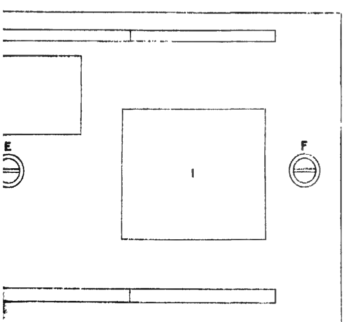


FIG.4. SECTION AT A.B.



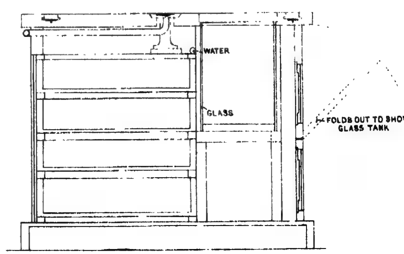
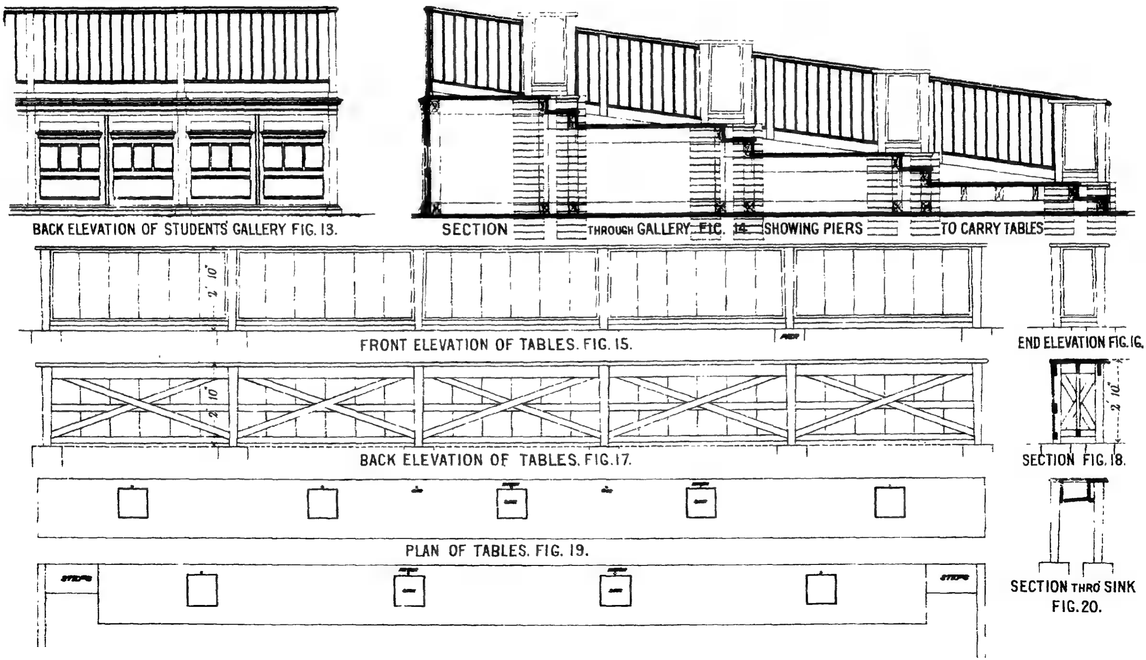


FIG.6. SECTION AT C.D.

PLATE 45.

YEDO. JAPAN.

COLLEGE OF ENGINEERING.



BACK ELEVATION OF STUDENTS' GALLERY FIG. 13.

SECTION THROUGH GALLERY FIG. 14 SHOWING PIERS TO CARRY TABLES

FRONT ELEVATION OF TABLES. FIG. 15.

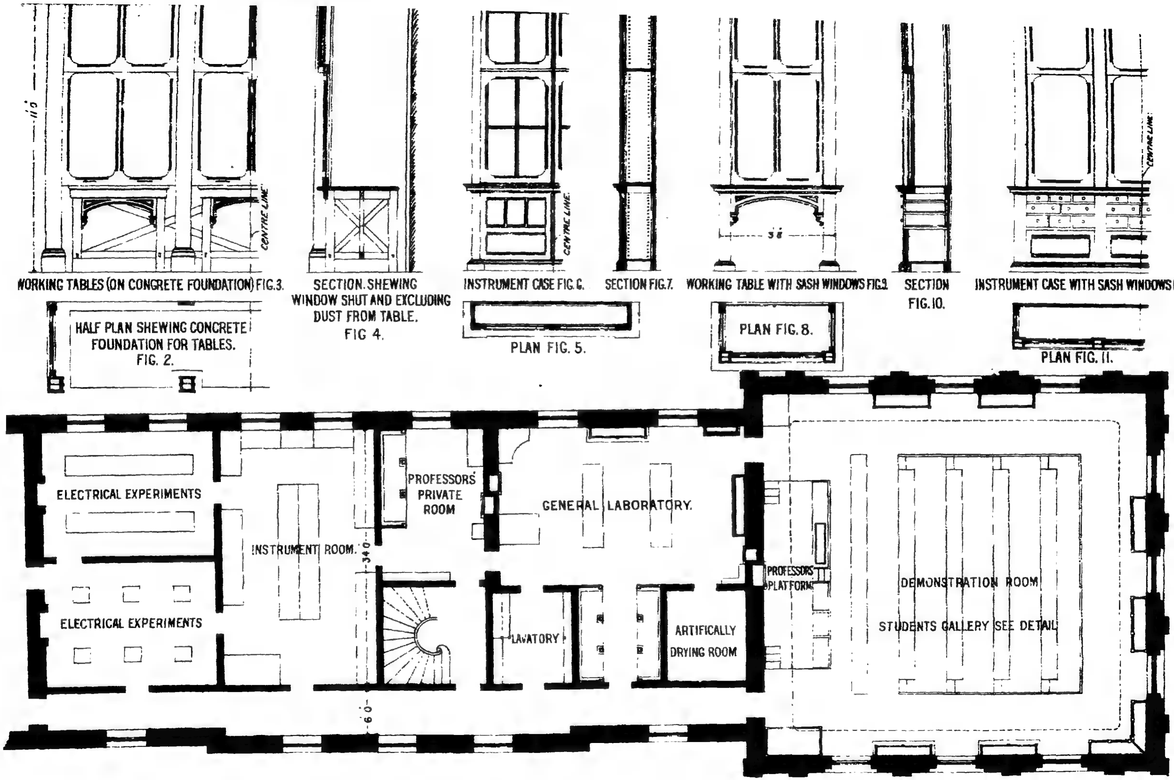
END ELEVATION FIG. 16.

BACK ELEVATION OF TABLES. FIG. 17.

SECTION FIG. 18.

PLAN OF TABLES. FIG. 19.

SECTION THRO' SINK FIG. 20.



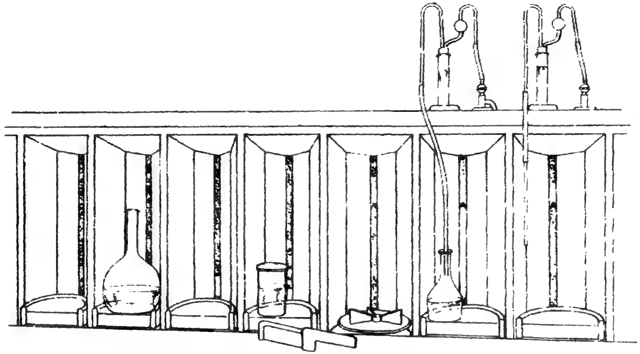
GROUND PLAN.

FIG. 1.

GRAZ.

SULPHURETTED HYDROGEN DRAUGHT CLOSETS BY PEBAL

NB. THESE ARE WITHIN AN ORDINARY GLAZED CLOSET.

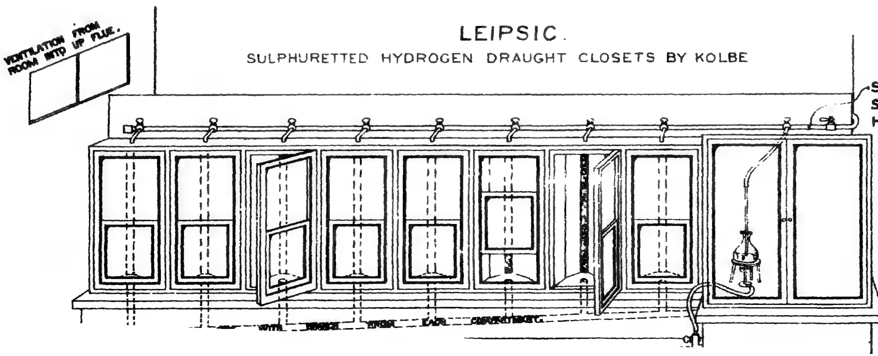


NOTE. THE SIDES OF THESE COMPA[TS] ARE OF PORCELAIN.

THE UPRIGHT SLITS (A) AT BACK OF CLOSETS ARE THE OPENINGS INTO EXTRACT FLUE.

LEIPSIC.

SULPHURETTED HYDROGEN DRAUGHT CLOSETS BY KOLBE



SUPPLY OF SULPHURETTED HYDROGEN FROM GASOMETER IN BASEMENT.

FIG.2.

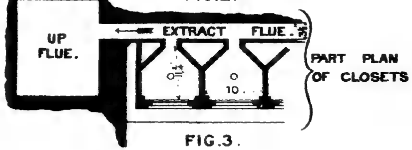
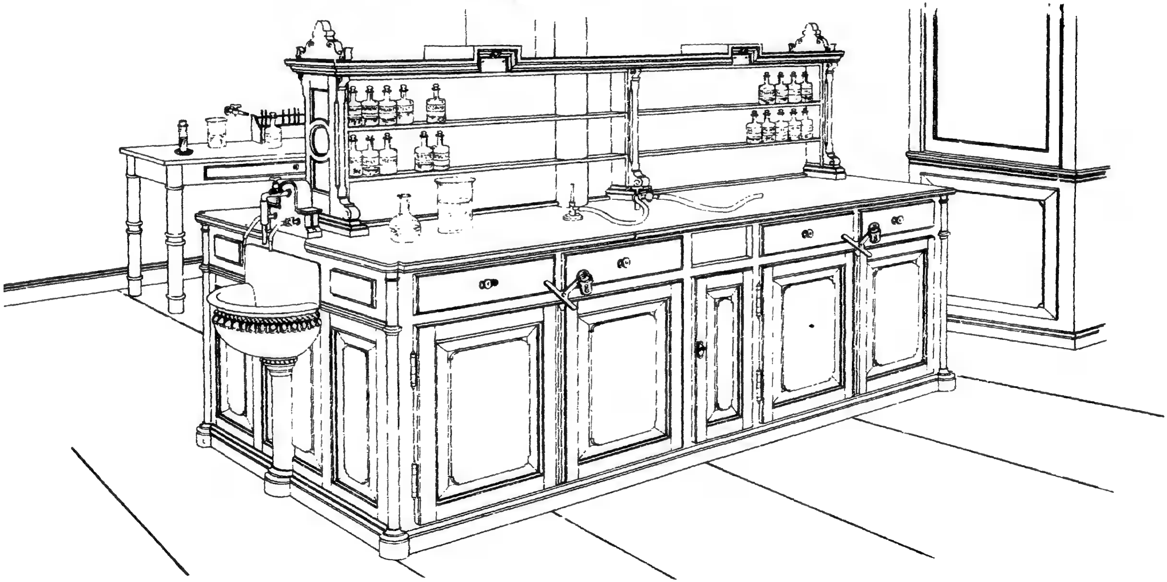


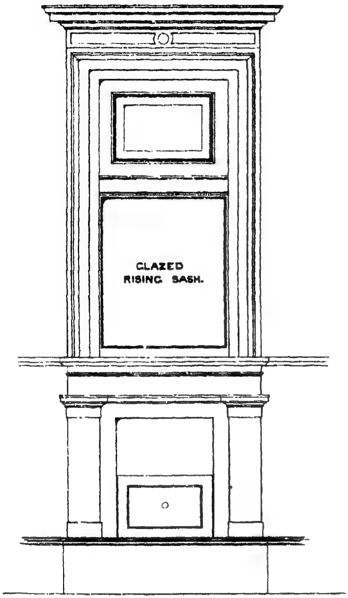
FIG.3.



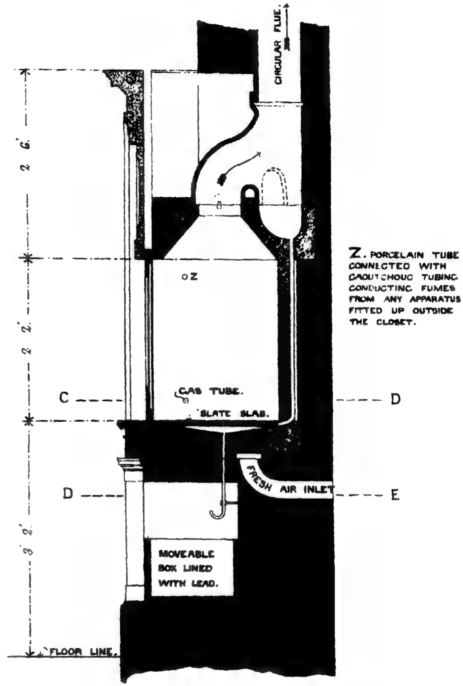
SKETCH OF ONE OF THE STUDENTS' WORKING TABLES.
FIG.4.

BONN AND BERLIN.

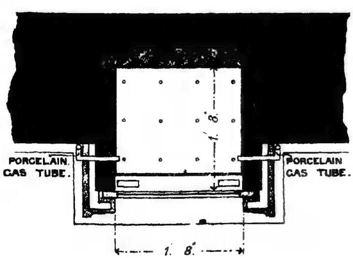
DRAUGHT CLOSET, BY HOFMANN.



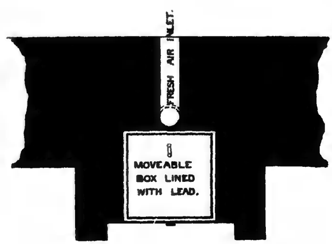
ELEVATION
FIG. I.



SECTION
FIG. 4.

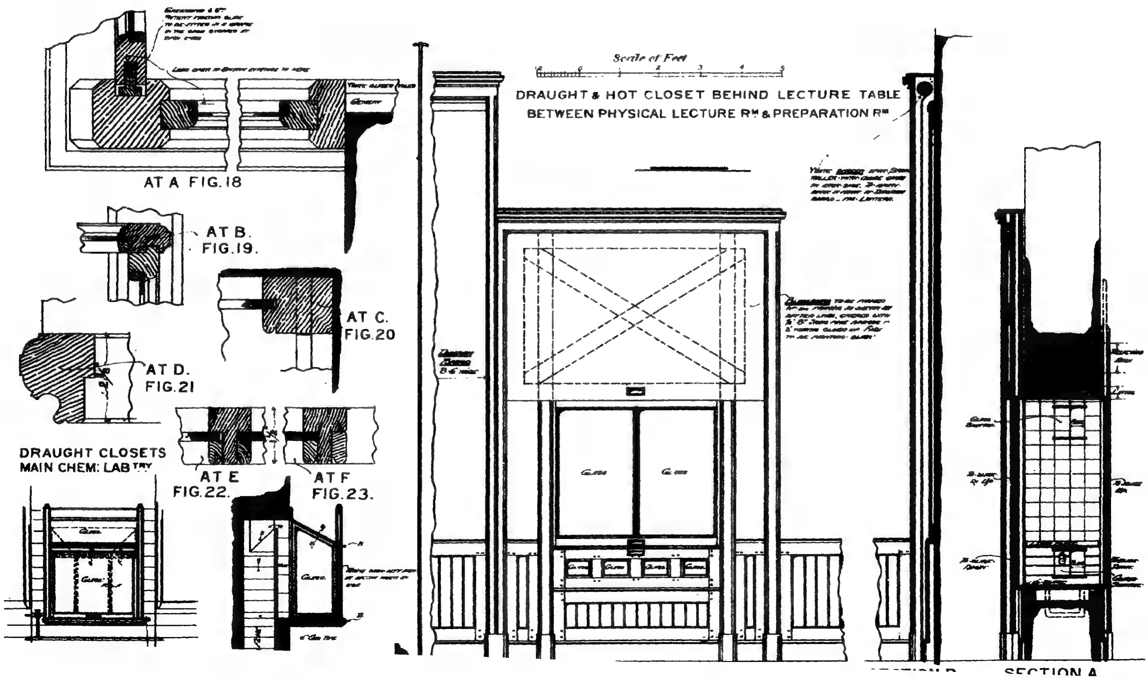


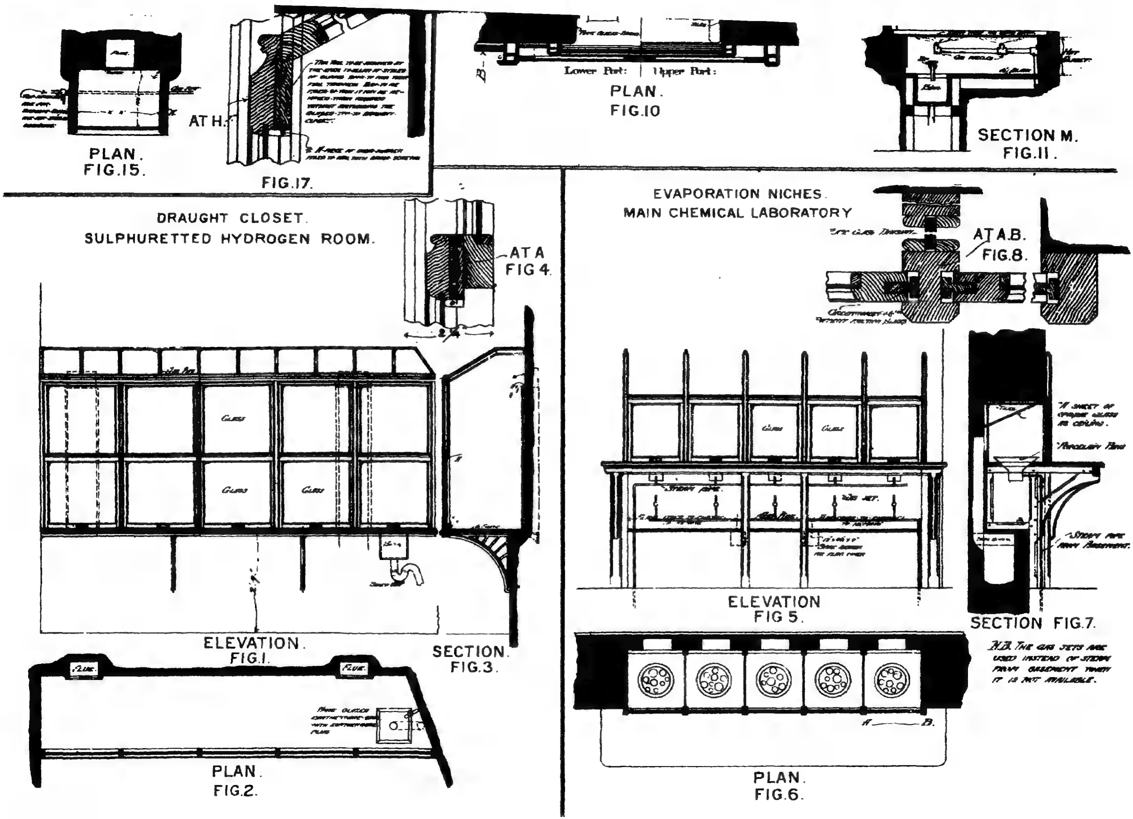
PLAN AT LEVEL C. D.
FIG. 2.

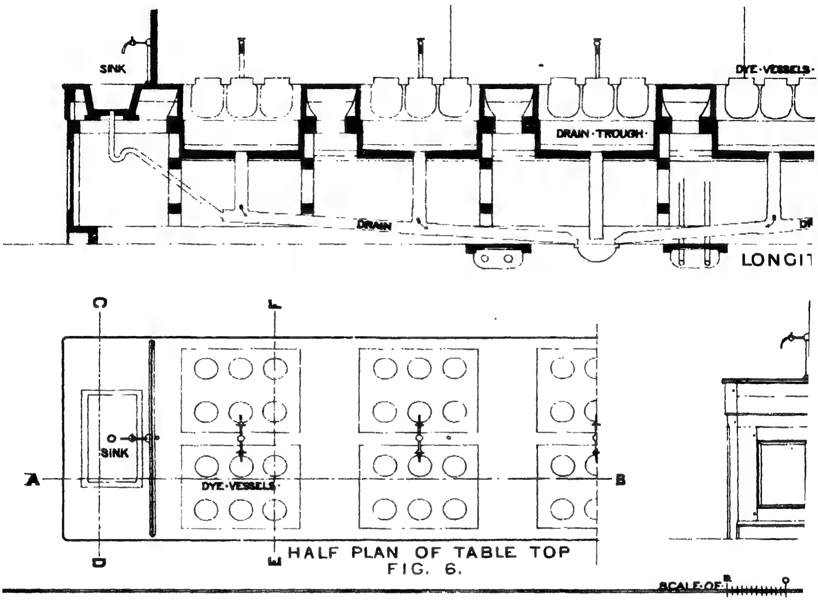


AT LEVEL D. E.
FIG. 3.

THE YORKSHIRE COLLEGE, LEEDS

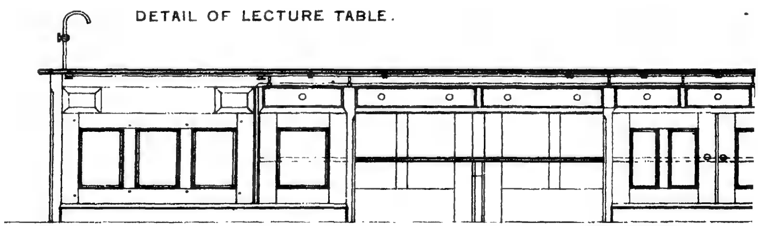



PLAN.
FIG.15.
AT H.
FIG.17.
Lower Part: | Upper Part:
PLAN.
FIG.10
SECTION M.
FIG.11.
DRAUGHT CLOSET.
SULPHURETTED HYDROGEN ROOM.
AT A
FIG 4.
Glass
Glass
Glass
Glass
ELEVATION.
FIG.1.
SECTION.
FIG.3.
Flue.
Flue.
PLAN.
FIG.2.
EVAPORATION NICHES.
MAIN CHEMICAL LABORATORY
AT A.B.
FIG.8.
Glass
Glass
ELEVATION
FIG 5.
Porcelain Pan
Steam pipe from basement.
SECTION FIG.7.
N.B. The gas jets are used instead of steam from basement when it is not available.
PLAN.
FIG.6.

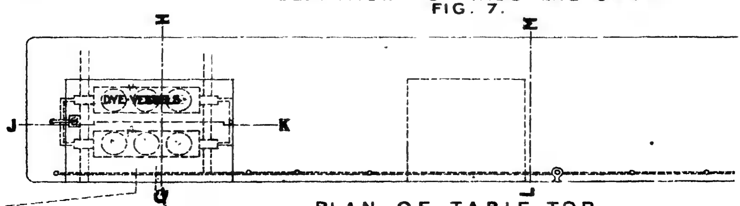


HALF PLAN OF TABLE TOP
FIG. 6.

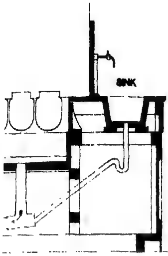
DETAIL OF LECTURE TABLE.



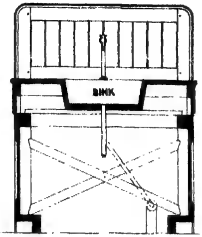
ELEVATION TOWARDS LECTURER.
FIG. 7.



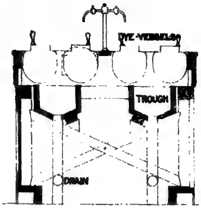
PLAN OF TABLE TOP.



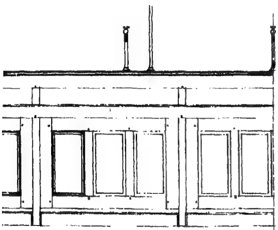
ECTION ON LINE A.B.
IC. I.



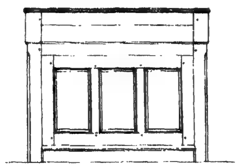
SECTION ON LINE C.D.
FIG. 2.



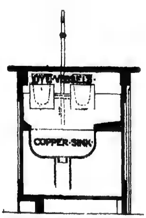
SECTION ON LINE E.F.
FIG. 3.



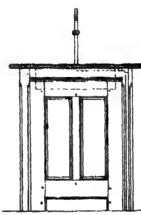
VATION OF TABLE.
FIG. 5.



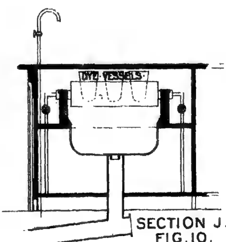
END ELEVATION.
FIG. 4.



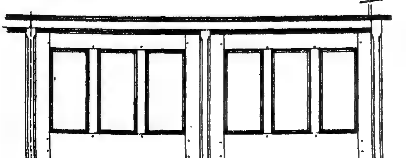
SECTION G.H.
FIG. 8.



END ELEVATION.
FIG. 9.

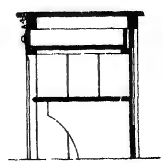


SECTION J.K.
FIG. 10.



HALF ELEVATION TOWARDS "PUBLIC".

FIG. 12.



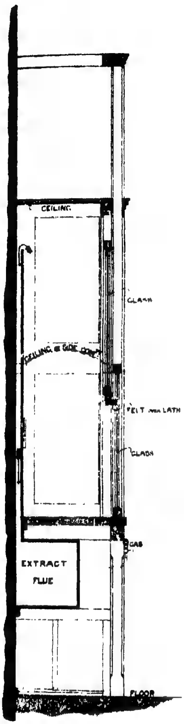
SECTION L.M.

FIG. 11.

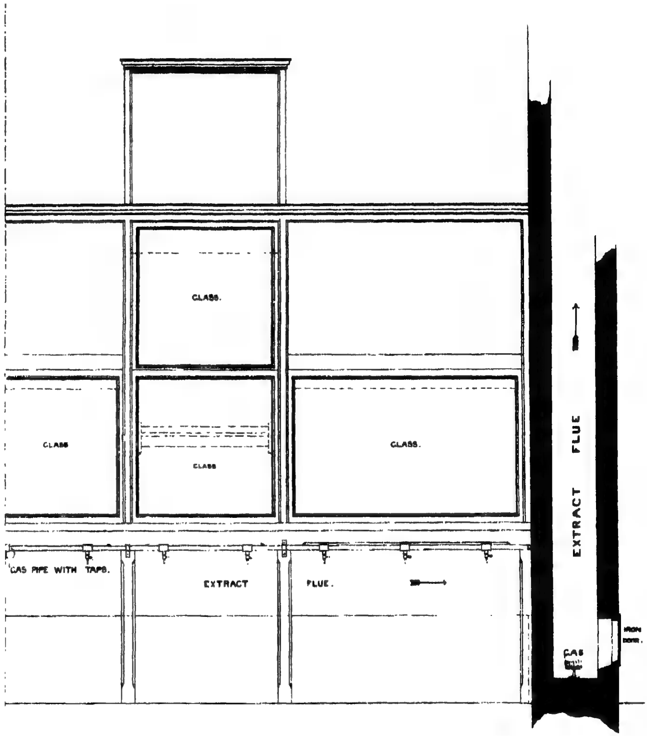
FINSBURY TECHNICAL COLLEGE.

PLATE 50.

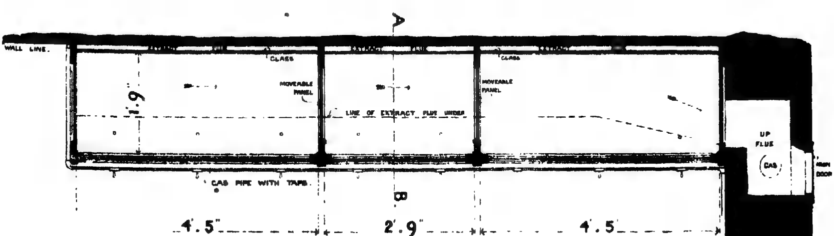
DETAIL OF DRAUGHT CLOSET.



SECTION ON A. B.
FIG. 1.



PART OF ELEVATION.
FIG. 2.

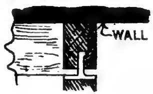


PLAN
FIG. 3.

FINSBURY TECHNICAL COLLEGE.

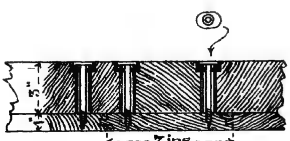
DETAIL OF BLACK BOARD.

AT C.
FIG. 4.

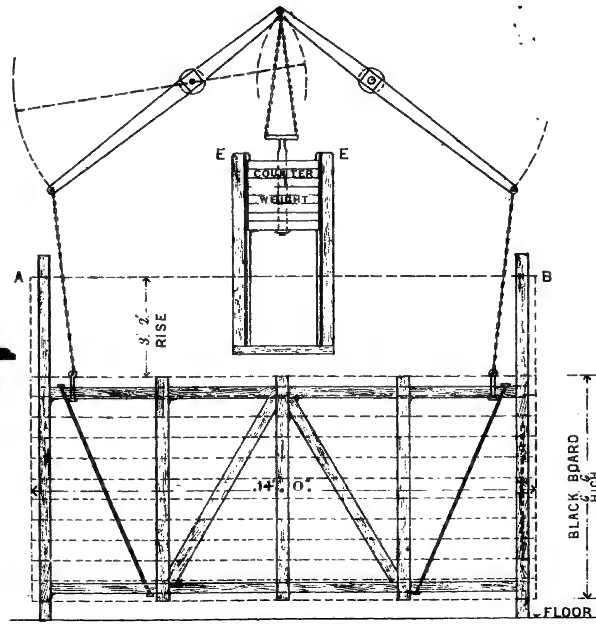


AT D.
FIG. 5.

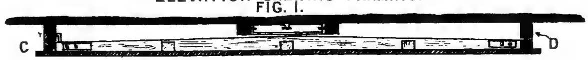
PLAN AT E. E.
FIG. 6.



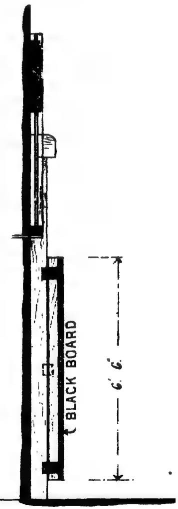
SECTION THRO. BATTENS &c
FIG. 7.



ELEVATION SHEWING FRAMING.
FIG. 1.



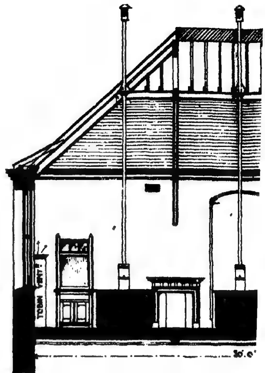
PLAN AT LEVEL A. B.
FIG. 2.



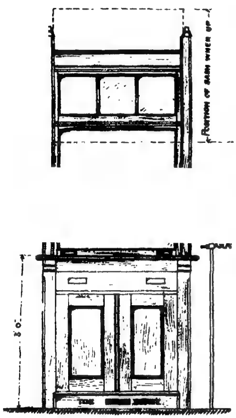
SECTION
FIG. 3.

SANDALL ROAD SCHOOL: NEW CH

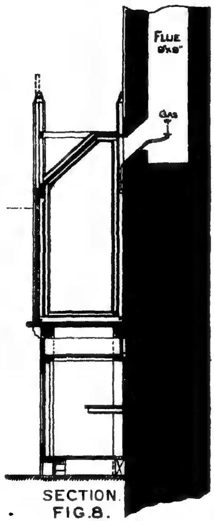
DETAIL OF DRAUG



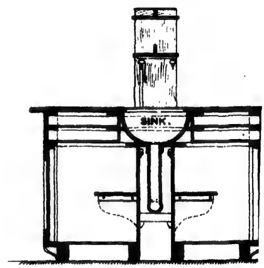
LONGITUDINAL SECTI
FIG



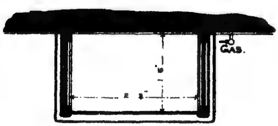
ELEVATION.
FIG.7.



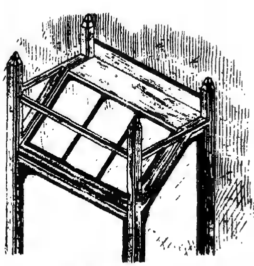
SECTION.
FIG.8.



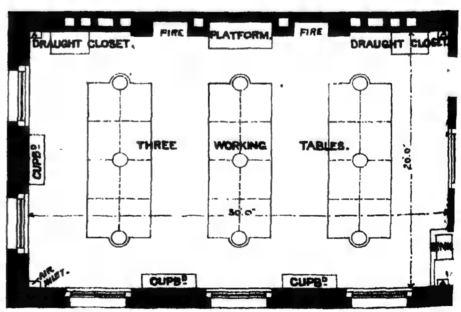
SECTION.
FIG.3.



PLAN.
FIG.9.



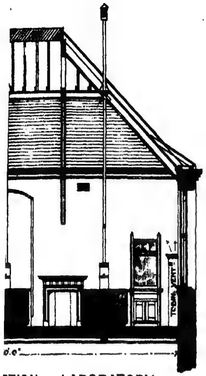
BIRDS-EYE VIEW OF ROOF
FIG.10.



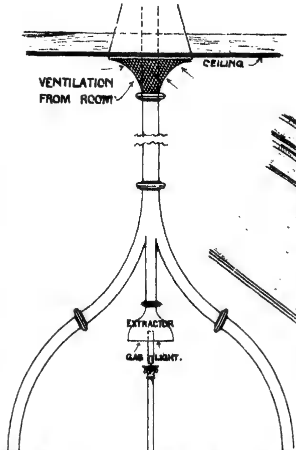
PLAN FO LABORATORY.
FIG.2.

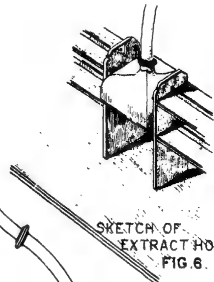
:HEMICAL LABORATORY. 1885.

UGHT CLOSET.

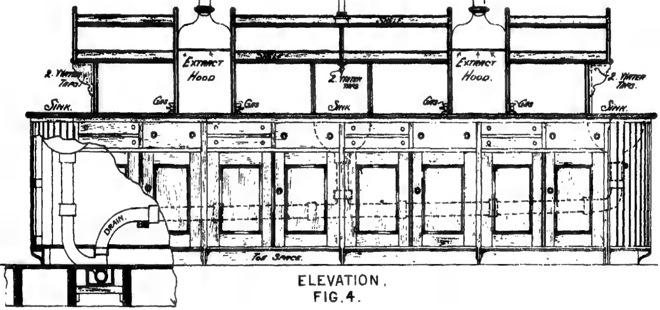


:TION OF LABORATORY.
FIG. I.

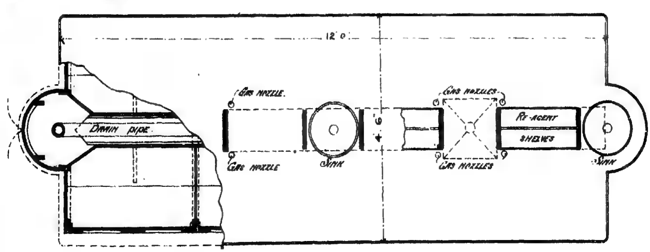




SKETCH OF
EXTRACT HOOD.
FIG. 6.



ELEVATION.
FIG. 4.



A PLAN AT VARIOUS LEVELS
FIG. 5.

DETAILS OF ONE OF THE WORKING TABLES FOR STUDENTS.

E. C. ROBINS, F.S.A. ARCHITEC

CHAPTER VII.

HEATING AND VENTILATION GENERALLY.

THE dependence of natural ventilation upon the pressure of the air provoked by winds or changes of temperature, will always make it necesssary to consider systems of ventilation side by side with warming.

By natural ventilation I mean that which follows natural laws, as distinct from ventilation which is the result of artificial mechanical contrivances, such as may result from the use of a fan, which forces the air in any direction desired, irrespective of its natural inclination to pass in the direction of least resistance, in obedience to the wind or to variations in temperature or both combined.

The most natural way of heating is like that of the sun in the heavens. Radiant heat is generally admitted to be the best means of warming limited spaces, because it warms the body without heating the air or prejudicially affecting its purity; but then it is very costly. Moreover, inasmuch as the effect lessens as the square of the distance increases, open fires are inefficient in the case of very large rooms, and have to be supplemented by convective or conducted heat; that is, by heating the air directly by heated surfaces of stone, earthenware, iron or copper plates, hot water, steam or gas-heated pipes. The passage of the air over such heated surfaces does not necessarily render it impure, provided always that the surfaces are kept clean and the temperature is not raised above 120 degrees—beyond that there is an unwholesome drying of the air; but absolute burning of the air can scarcely take place where hot water or steam only are employed.

To overcome the dryness of the air, and at the same time to cleanse it of impurities, it has been found desirable to pass the incoming air through a water-spray fixed in the centre of the inlet-opening for air. But in this case the humidity of the passing air is apt to increase the tendency of the iron pipes or steam cases to rust, and so to affect the air prejudicially, especially when propulsion is used. To obviate this, it is desirable to Bower-Burff all heating surfaces or galvanize the same, so that they may not corrode, and be readily dusted and kept clean.

The smell from heating surfaces is commonly owing to the dirty condition of the pipes or cases, and it is therefore of great importance that they should at all times be get-at-able for cleaning.

Hot-water pipes are of two kinds, cast-iron of some 3 or 4 inches' diameter, in which the water is not heated above 200°—called low-pressure piping—and wrought-iron pipes of little more than an inch in diameter, in which the water is heated to 300° or even 350°, which is called high-pressure piping.

In the former the water is heated in a boiler, from which the water circulates by flow and return pipes, outlets being provided at the highest points for the escape of air. In the latter, called Perkin's system, there is no boiler, but the furnace-chamber is surrounded by coils of the circulating piping, upon which the fire plays, and thus any number of flow and return pipes may be provided from the same furnace. Expansion tubes are fixed at the highest points of the apparatus, and cleansing valves at the lowest. It is desirable to fill the pipes with a non-freezing solution of chloride of calcium and water.

Heat can be conveyed to a greater distance by the use of steam-piping than by any other medium, and where a steam-engine is required for other purposes, the waste steam may be economically employed for heating. Steam chests or cases are usually surrounded with iron gills, to increase the area of the heating surface.

In the low-pressure system, Mr. Hood gives rough and ready rules, which, however, are not equally applicable in all cases, for obvious reasons. He says 5 feet of 4-inch pipe will warm 1000 cubic feet in a public room to 55°; 12 feet of the same piping will warm every 1000 cubic feet of a dwelling-house to 65°. In shops 10 feet, and in workrooms 6 feet per 1000 cubic feet are sufficient. About two-thirds of high-pressure piping will realise the same results by this "rule of thumb," on account of its higher temperature.

One of the best practical treatises on heat as applied to the useful arts, is that of Thomas Box; as an *aide-mémoire* to the architect and engineer it is invaluable. The authorities from whom the experimental data, &c., are derived, are for the most part given as they occur; but Péclet's great work, "*Traité de la Chaleur*" should be more particularly mentioned. The book opens with a chapter on general principles. "It is necessary," says he, "to have a standard for measuring the amount of heat absorbed or evolved during any operation,—in this country the standard '*Unit*' is the amount of heat required to raise the temperature of a pound of water at 32°, one degree Fahrenheit.

"Different bodies require very different quantities of heat to effect in them the same changes of temperature. The capacity of a body for heat is termed its '*Specific heat*,' and may be defined as the number of units of heat necessary to raise the temperature of one pound of that body one degree Fahrenheit."

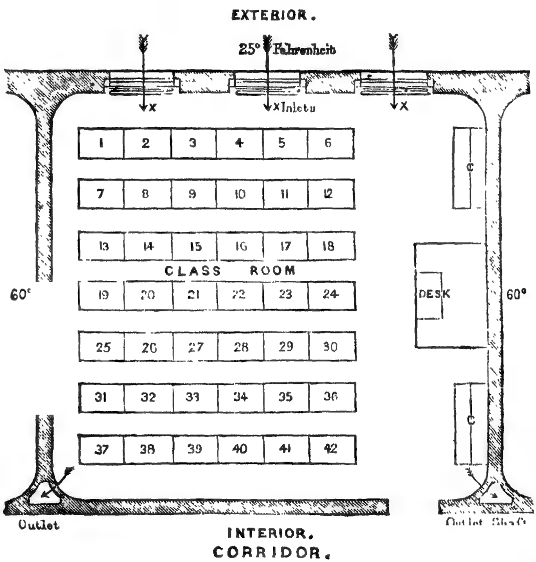
The successive chapters on combustion, steam-boilers, efflux of air, chimneys, vapours, evaporation, distillation, drying, heating liquids, heating air, the transmission of heat, and laws of cooling, and on ventilation, conclude with examples of buildings heated and ventilated, and the effects of wind on ventilation. The chief merit of the book is its terseness, its abundant formulæ, and fullness of tabular calculations based on the principles laid down by the latest English and foreign authorities.

In the next chapter I shall give an abstract from the appendix of my paper on "Sanitary Science in its relation to Civil Architecture," read at the Royal Institution of British Architects in 1880. The said abstract is an argument differentiating the com-

parative economic value of different systems of heating, &c., worked out in detail by Mr. A. J. Bacon. At that period this gentleman was practising at Antwerp as an engineer and manufacturer of heating apparatus. I had long been acquainted with his father as the chief of the firm of J. L. Bacon and Co., of London, by whom many of my churches and schools had been heated.

Mr. A. J. Bacon had finished his education in Germany, and had become familiar with the German and Belgian practice. He told me that he found quite a different sort of intelligence was brought to bear on this subject in those countries; that the architects were well up in the science side of the matter, as well as its practical appli-

PLAN.



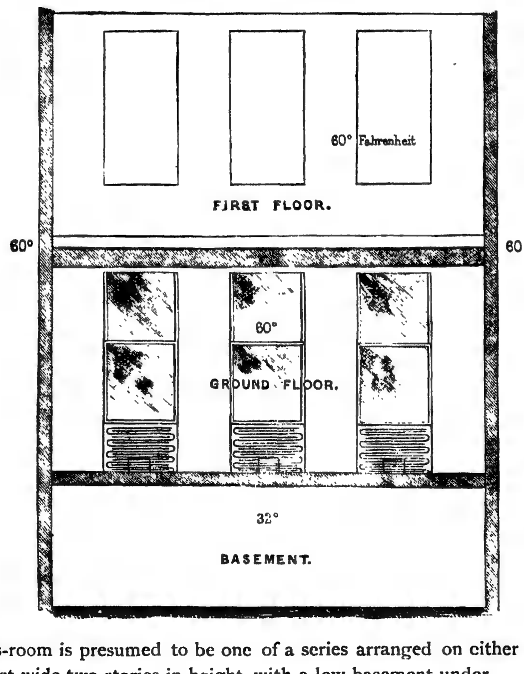
cations, and that they demanded a more complete theoretical as well as practical elucidation of the particular schemes presented for their choice, than is at all common in this country. It occurred to me, therefore, to ask him to give me the solution of the following proposition, as an illustration of the method of calculation he was accustomed to employ in his Belgian practice, and I handed to him the accompanying plan and section of a single class-room, with the following particulars :—

PROPOSITION.

Required, the apparatus necessary for properly heating and ventilating a class-room for forty students; inlets and outlets being provided for changing the air, say, four times in the hour.

A class-room for 40 (the diagram shows benches for 42) pupils in a secondary school or college, wherein 15 square feet of area are allowed for each pupil, requiring a room measuring 25 × 24 feet. The height of the room to be a clear 13 feet—the angles of the room being rounded at a radius of 2 feet; 60° Fahr. to be maintained per hour as a constant temperature concurrently with a change of air at the rate of 700 cubic feet per head; the windows to be on one side and on the left of the pupils, and to measure 9 feet high by 4 feet wide; the door to be in the opposite wall, left of the teacher. There would be accommodation, in desks opposite the teacher, for seven desks in a row, six rows deep with interspaces.

SECTION.
THRO' CLASS ROOM.



The class-room is presumed to be one of a series arranged on either side of a central corridor 10 feet wide two stories in height, with a low basement under.

The minimum thickness of wall is imagined, namely, 14-inch outer walls and 9-inch internal walls.

The class-rooms on each side of it and the room over it, as well as the room itself, are supposed to be heated to a temperature of 60°, while the outside temperature is 25°, and the corridor 50°.

The artificial system of heating may be by hot water, either high or low pressure, or steam apparatus.

The inlets for fresh air are to be at the lower part of the centres of the window-backs, and the air is to pass through the hot-water or steam coil or box occupying the whole of the window-back, the openings from which to be at the top of the case.

The outlets are to be opposite the windows, in the spandrils of the corners, and in the winter to open at the bottom of the room, and in the summer at the top, and are to be under control.

DEMONSTRATION.

The method of calculating the losses of heat, the areas of the inlet and outlet shafts, the consumption of fuel, &c., would be as follows:—

The amount of heat required to keep the class-room at its normal temperature would be the sum of the quantities $d+a-c$: where d=heat lost by radiation and conduction of the outer surfaces, a=heat necessary to warm the incoming air, and c=heat given off by the children. For convenience of calculation these various quantities are usually reckoned for the fixed period of one hour.

Heat lost per the walls, &c. The amount of heat lost by any surface varies with its nature and thickness; but the calculations necessary to determine such losses are very involved, and too abstruse to be entered into here. We can, therefore, only state the coefficients necessary for determining the loss in the supposed instance, which are per degree Fahr. difference of temperature (see *Practical Treatise on Heat*, by Thomas Box, London, 1880):—

9-inch wall (brick)	0·275	units per □ foot.
14-inch ditto	0·213	"
Glass	0·53	"
Floor	0·164	"

Applying these to our case, we arrive at the following results:—

14-inch outer wall	$[\{(25 \times 13) - (3 \times 9 \times 4)\} (60 - 25) 0{\cdot}213]$	= 1617	units.
Windows	$(9 \times 4 \times 3)(60 - 25) 0{\cdot}53$	= 2003	"
9-inch wall towards corridor	$[\{(25 \times 13) - (8 \times 3{\cdot}5)\} (60 - 50) 0{\cdot}275]$	= 816	"
Door in same	$(8 \times 3{\cdot}5)(60 - 50) 0{\cdot}53$	= 148	"
Floor	$(25 \times 24)(60 - 32) 0{\cdot}164$	= 2755	"
		7339 units = d.	

Heat necessary for ventilation. The quantity of fresh air necessary being 700 cubic feet per head per hour, and the number of children in the class—40, it is evident that, allowing for one teacher, $700 \times (40+1) = 28{,}700$ cubic feet must be admitted. Since the volume of air varies directly with the temperature and the "specific heat" inversely, it is usual to reduce quantities of air to weight in lbs., in order to be able to neglect these variations. Thus, supposing that the fresh air is taken from outside at 25°, its volume at that temperature, calculated by Regnault's rule,

$$458{\cdot}4 + t$$

would be 26,761 cubic feet only, but the weight would remain the same :—

$$\frac{28700}{13 \cdot 1} = 2191 \text{ lbs.}$$

and 0·238 units being the specific heat of air, the heat necessary to raise this weight of air to 60° would be

$$2191 \times 0{\cdot}238\,(60 - 25) = 18242 \text{ units} = a.$$

Heat given off by the children. According to M. Dumas, the quantity of carbon given out by an ordinary person is ·022 lb. per hour, and the heat thus developed is 12906 × ·022 = 284 units per hour. A considerable part of this heat, however, is absorbed by the vapour formed during respiration, and becomes latent, the amount from 62° being ·0836 × (1178 − 62) = 93 units. The remainder, therefore, available for heating purposes is 284 − 93 = 191 units. In our case, therefore, we have :—

$$41 \times 191 = 7831 = c.$$

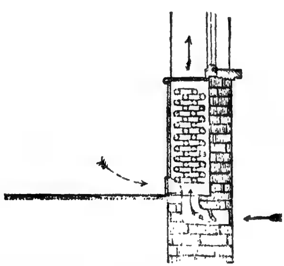
Setting the various values obtained, according to our formula $u = (d + a) - c$, we find :—

$$u = 7339 + 18242 - 7831 = 17750 \text{ units.}$$

The above equation shows—that while the walls lose a certain proportion of heat, this is more than supplied by the children themselves; and that after the normal temperature has been attained, the apparatus serves really to cool the room down, instead of heating it, inasmuch as the air entering would only be heated to :—

$$25 + \frac{17750}{2191 \times 0{\cdot}238} = 59°$$

The best manner of arranging the heating surfaces would be in stacks, underneath the windows and recessed in the walls, connected directly with the outer air by means of an opening under them, opened and closed alternately, with a similar opening from the room at their base, thus (see woodcut) :—



The coverings for these coil recesses should be of cast-iron, in order to benefit as much as possible from the radiant heat.

When heating the room, the opening under the coil would be closed, and that in the front and at the base of the coil-box opened—so that the temperature may be the more quickly raised, inasmuch as the internal, instead of the external, air is circulated through the hot box. When, however, the class commences, and ventilation is required, this principle is reversed, and the cold air enters the box. The air thus heated may be allowed to pass through gratings in the window-sill directly into the class-room, or, if preferred, up shafts constructed in the piers between the windows, and into the room through openings near the ceiling. In our case, where the air would not enter at a high temperature, the former arrangement is preferable, because there is no difference of temperature between the inlet shafts and the room itself to actuate the current, and the

latter would therefore be induced solely by the extract apparatus—and since this would exert an equally powerful influence on the window cracks as on the shafts, the result might be very doubtful.

A further advantage of the former arrangement is that the currents of hot air, passing in front of the windows, tend to neutralize their cold radiation.

As already stated, the motive power of such an apparatus is the extract shaft. This can either lead directly up through the roof to the open air, or be taken down to the basement, and there connected with a common upcast shaft.

Granted that we ventilate our class-room by shafts leading directly up from the floor level to the outer air. Having a floor above of similar height and the pitch of the roof above that, we may assume 40 feet as the height of our shaft. The temperature in the same would naturally be that of the room, 60°, and for the outer air we can take the mean temperature—say, 50·4°. Calculating by Wölpert's formula :—

$$v = \sqrt{\frac{2gh\,(T-t)}{459+t}}$$

v being velocity in feet per second, h being height in feet, T temperature of shaft, t that of external air, our case would give :—

$$v = \sqrt{\frac{64{\cdot}35 \times 40\,(60 - 50{\cdot}4)}{459 + 50{\cdot}4}} = 6{\cdot}96 \text{ ft. per second, as the theoretical velocity.}$$

According to Péclet (see *Traité de la Chaleur*, by E. Péclet, Paris, 1878), however, 60 per cent. of this is lost in practice through friction, and we must therefore only calculate on a velocity of $6{\cdot}96 \times 0{\cdot}4 = 2{\cdot}78$ ft. per second. The velocity being thus determined, the area required for the extract shafts is readily fixed, namely :—

$$\frac{28700}{2{\cdot}78 \times 60 \times 60} = 2{\cdot}86 \ \square \text{ ft.}$$

On the first floor even a greater section would be required, since there would only be 26 ft. of height available to promote draught, and the equation would become :—

$$v = \sqrt{\frac{64{\cdot}35 \times 26\,(60 - 50{\cdot}4)}{459 + 50{\cdot}4}} = 5{\cdot}6 \text{ ft. per second,}$$

which, multiplied by 0·4, gives a real velocity of 2·24 ft. and an area for the shafts of 3·57 □ ft. It is evident, therefore, that to ventilate naturally by chimneys leads to the use of very large shafts, where the renewal is great, and hence is not of practical utility in cases such as the one under consideration. Of course a higher temperature might be obtained by rarifying the air passed up these flues in some way—either by placing heating surfaces similar to those used in the apparatus for warming, or gas-jets at their base; but since for every degree of increased temperature we should require $2191 \times 0{\cdot}238 = 521$ units of heat per hour, involving the burning of $\frac{521}{7500} = 0{\cdot}07$ lb. of coke in the furnace or boiler, it is manifestly expensive, both in the first instance and in the long-run.

It is the more inexpedient seeing that, wherever a heating apparatus, of whatever system, is introduced, there is always a ready means of ventilating at hand—at once inexpensive and powerful.

not enough to provide for the *extraction* of air *without* providing for its *incoming*, because the effort of natural forces seeking equilibrium will cause the air to be drawn through every crevice in doors and windows, and even through solid walls and floor, creating currents of air *en route* to the motive power, the partial vacuum which the fire in the grate produces. Neither is it sufficient to provide for the *admission* of air, if there is *no means* of *outlet*, and if the chimney-flue is closed it will not enter of itself at all, but will require to be forced into the room, by which process the occupants of the apartment will feel no more delightful sensation than used to be experienced by a descent in the diving-bell at the Polytechnic. In ordinary houses the chimney is a sufficient ventilator when associated with a means of feeding the chimney with a supply of air, to prevent it feeding itself by drawing from every crevice as afore-mentioned. To feed the fire directly, however, would probably prevent the draughts, but it would decrease the warmth, and leave the room unrefreshed by the change of fresh for expired air. Consequently, it is obviously desirable to introduce the air in such a way that it may do all the good it can before it reaches the fire and is swallowed up by the chimney current. Now it is admitted that the ordinary current up the flue of a sitting-room fireplace is at the rate of from 3 to 6 cubic feet per second, or 300 cubic feet per minute, or 18,000 cubic feet per hour. Consequently allowing 1000 cubic feet of air per hour as necessary to be extracted for each occupant of any chamber, obviously one sitting-room fireplace is a sufficient extractor for eighteen persons; if 3000 cubic feet are insisted on, as recommended by Dr. de Chaumont, then six persons are efficiently provided for by this means, which is all sufficient for all practical purposes in dwelling-houses, except on party nights, when a still larger volume of expired air will be required to be extracted, to make way for the equivalent of fresh air which it is necessary to introduce, to keep up the interchange and to maintain the purity of the air generally. Proceeding on this assumption, Mr. Tobin has the credit of putting in practice an old suggestion by the application of vertical fresh air shafts. But the entrance of air through these shafts has to be regulated. This may be done by a hinged lid on the top, with side cheeks opening towards the wall, or by a diaphragm plate hung on centres in the middle of the length of the shaft, and turned with a brass handle at pleasure. In the next place, dust and smoke blacks find their way into the room along with the so-called fresh air. At first, perforated zinc was put in and failed, then cotton-wool was lightly put over, which upset the whole principle by checking the current which was needed to carry the air to the top of the room, so that it might fall like the spray of a fountain by its own gravity, only weakened as its temperature was raised by contact with the upper strata of the air of the room.

The Sanitary Engineering and Ventilating Company have contrived a distinct improvement by making use of the horizontal part of the inlet pipe or elbow which passes through the wall as a trap to catch the blacks, by directing the incoming air through iron plates, set at an angle to cause the air to be thrown on the surface of the water, which is held in a tray over which the air must pass. But this freezes in winter, and at Christmas parties, when most air is required, the chances are it is frozen, and the blacks must enter with the air. This has led to another plan being substituted: a canvas bag of the shape of a dame-school fool's-cap is fixed inside, and the air passes freely enough through the

extended meshes, and comes in pure and in sufficient force. The lower in the shaft the bag is fixed the better, but it requires frequent changing for cleaning.

The double-hung rising sashes, which I prefer to any other sort of sashes, give a similar kind of access for air, by simply raising the lower sashes 2 inches and fixing a piece of wood to fill up the space below: between the upper part of the lower sash so raised and the lower part of the upper sash which is closed, there will be a space through which the air will pass in an upward direction. Or the same end may be attained by cutting slots in the meeting rails of the sashes, and fixing hit-and-miss brass ventilators over the slots and so admitting or excluding the air at pleasure. Tonks, of Birmingham, has presented to the Museum Currall's patent for admitting air vertically through the pierced bottom rail of window sashes covered by metal plates directing the current. By no other means is the introduction of cold air directly from without admitted with an upward current at a low level, except through Pierce's pyro-pneumatic, Boyd's last new hygiastic, and H. S. Snell's thermhydric stove; these and others like them stand free of the wall, and the air is brought from without and passed through vertical shafts within the stove-case into the room.

There is a variety of other stoves, which in summer are to be used as cold air admission inlets, so also there are a great many wall ventilators, but none of them deliver the air into the room with a vertical current. At best it is with a cant upwards at an angle of 45° towards the ceiling, like the Sherringham wall ventilator.

Stevens's drawer ventilator, of which an example may be seen in the Parkes Museum, is an attempt to achieve a vertical current from a side opening, but it is not sightly.

Crossley's improved louvre ventilators, both for the admission and extraction of air, are good of their kind and may be seen there.

Boyd, Batty, Edwards, and many stovemakers, arrange for the admission of fresh air through the stove fronts, and very valuable is this means of inlet, because it can be regulated to a nicety by the handle furnished to open and close the louvres, which, in the case of Boyd's School Board stoves, are provided.

In winter time, the value of the introduction of fresh air through the stove is most obvious, because, by taking off the extreme coldness of the outer air, by causing it to pass over warmed surfaces on its way to replace the air exhausted by the attraction of the fire flue, less amount of fuel is required to heat the air of the room than if it came in at the same temperature as the outer air. It is therefore a matter of economy that influences the rejection of any plan which introduces crude cold air, even though it is done without draught on the Whitehurst principle.

The difference between the temperature of the air in the entrance-hall and staircase of a house has led to the introduction of door ventilators, for the admission of the cooler air of the hall through brass hit-and-miss ventilators set in the top rail of the door, but this was found to bring the draught straight down upon the occupants between the door and the fire, and consequently Currall's patent door ventilators were invented, to establish an upward current. This principle has received a further development by the architrave ventilator, an apparatus designed by Mr. Judge, formerly the curator of the Parkes Museum. In ordinary dwelling-houses hot-water heating is rarely introduced, but if it were, then a most

convenient mode of introducing air is available by passing it through a chamber surrounded by a coil of hot-water pipes.

I have now considered the various means of admitting fresh air, and my preference for the preservation of a vertical current is obvious, and even where that cannot be obtained I think that air should never be introduced directly, but always through a flue built in the wall at a lower level than the opening into the room, so as to break the force of the wind, but at the same time to encourage a vertical current.

Let me now consider *Extract Ventilators;* at present I have remarked only upon the chimney-flue, but there are occasions when it is desirable to supplement this flue, and sometimes there is no fireplace at all, and consequently no chimney by which to ventilate. But supposing that a fireplace *does exist* it is common to supplement it by other appliances: of these Dr. Arnott's chimney-valve is the earliest, and with its varieties, the most generally accepted; they are usually fixed near the ceiling and form a communication between the upper air of a room and the heated chimney-flue in winter, when there is a fire; and where there is *no down draught* they answer very well, provided proper inlets for air, equal in area to the outlets, are included in the arrangements. In summer, they are also available as ventilators, but down draught is common in flues where there are not fresh-air inlets, or that have no fire to provoke a partial vacuum and consequent upward current therein, the air descending the sooty flue and penetrating the chinks around the talc flaps (intended to close tightly but rarely doing so); a disagreeable smell is often introduced by this means, so that for this and other reasons I am not much in favour of ventilating in this way by the chimney-flue. I prefer that a separate flue should be constructed for this purpose, which, going up with or between the heated smoke-flues, is sufficiently warmed to rarefy the air and increase the upward current. This special air-flue should be carefully pargeted or lined with plaster, and should not open at the top of the chimney-stack on the same level as the smoke-flues, but should open through metal or slate louvres on opposite sides of the stack and about 3 feet below the top. But if it be objected to, as it often is, by those who cannot abide spending money in any form of ventilation—contenting themselves with Mr. Hinckes Bird's so-called costless ventilation (which of course is infinitely better than *none*, and oftentimes is found more effective than *much* that is made to come very expensive)—I say if it is objected to, that this would be equal to doubling the size of the chimney-breasts and backs, then, *don't do it*, but adopt the simple but most efficient plan suggested by Mr. Boyd over thirty years ago, and which I myself have carried out in large and in small buildings, but which is particularly suitable for dwelling-houses. Instead of making the withe or division between the flues of solid half-brickwork (4½ inches), make it a hollow flue by the introduction of cast-iron flue-plates, the thickness of a slate, leaving a clear 4 inches for a ventilating flue warmed on either side by the smoke-flues between which it is situated, and occupying no more space than the ordinary flue withe. I have used these flue-plates to form extract ventilating flues, for the last twenty years, with uniform success. Ordinarily it will be found that there is a sufficient upward draught in extract flues, such as these which I have now described, to form proper exhaust shafts, provided always inlets for fresh air of the same area also exist,

but if from any cause there is a failure in the upward current and a down draught is the result, then there are many simple mechanical means for overcoming the evil. In the first place there is a variety of cowls so constructed that the action of wind passing by them shall overcome the stagnation of the air in the flue, and give it a tendency to follow in the direction in which the wind is inclined by the form of the obstruction which the cowl presents to its progress. Such cowls are made by Kite, Howorth, Verity, Boyle, Buchan, Banner, and a host of smoke doctors and house-drain ventilators, and sanitary reformers generally. Some of these are exhibited in the Parkes Museum. But expired air, ventilating or exhaust shafts, carried up with the smoke-flues, and therefore opening to the air on the sides of the chimney-stacks through louvres 3 feet below the top of the stacks, cannot have cowls to help the upward draught. In these cases the motive power may be applied at the foot of the shaft, by the application of a small " Bunsen " burner gas-jet just within the grating, through which the vitiated air makes its escape into the upcast flue. Such ventilators so furnished are made by Mr. Boyd, of 19, Maddox Street, Regent Street. For many years I have used these appliances, and they may be seen in action at various public buildings erected by me, namely, the National Industrial Crippled Boys' Home, Kensington, the South Hampstead High School, the North London Collegiate School for Girls, and in the class-rooms and science lecture-rooms of other buildings.

The introduction of fresh air and the extraction of foul air, simultaneously, both at the upper part of a room, has been attempted with considerable but not unvarying success, by Mr. Potts of Charing Cross and Birmingham. It consists of a metal, or carton-pierre, or papier-maché, or other hollow cornice, taking the place of the usual plaster cornice, which cornice is divided longitudinally for the whole length of it by a plate attached to the lower portion. The fresh air is admitted from without to the lower horizontal division of the cornice, and is passed into the room through ornamental perforations in the bed mouldings of the cornice. The foul air is extracted through similar perforations in the upper part of the cornice, giving access to the upper horizontal division of the cornice, the outlet pipe from which is taken to an air-flue built in the wall, with a cowl on top or a gas-jet at bottom, or into a smoke-flue, the kitchen chimney flue being preferred as the hottest and most generally available at all seasons of the year, for we must dine! Mr. Robson, late architect of the London School Board, has spoken in commendation of this plan as follows :— " I can speak strongly in its favour for facility of application, sightliness, economy of first cost, and self-acting properties. In the case of new buildings, where warm vertical air-flues can easily be provided, its action must be so perfect as to induce a very general adoption of the principles of the system."

But it is time that I passed on to the subject of lighting and warming, not that they can ever be treated without reference to ventilation, but rather because ventilation cannot be studied or practised without due consideration of the mode of heating and lighting, intended to be adopted in the room to be ventilated. Indeed, the temperature of the air within a room and without it, being different in density, in the proportion that either is hotter or colder than the other, is one cause of the pressure of one atmosphere against another atmosphere in search of that equilibrium which nature is ever seeking and never

finding for any length of time together. "The whistling wind rushing through the woods and forests, bloweth where it listeth, and we cannot tell whence it cometh or whither it goeth," until we have traced to its source the provocative cause, which will be found to arise from variations in humidity and temperature and consequent density of pressure of the heavier against the lighter and brighter atmospheres, with which the former impinge against the latter. Thus the draughts in a room are the result of the pressure of the cold air of the street or passage in its struggle to get to the warm air of the room, and particularly to that part of it whence the heat is generated and projected. Where two rooms are of the same temperature the air is stagnant, that is to say, no movement of the air from one to the other will take place by the opening of a means of communication between them. It is obvious, therefore, that if the whole of the interior of a house were equally warmed there would be no change of air between one part of the house to another, and the building would be in the most favourable condition for the introduction of the means of special ventilation already described. Each room might be separately lighted, warmed, and ventilated, and yet the same temperature might be maintained, but with the difference that there would be no stagnation, but pure fresh air warmed as it entered for free inspiration, and withdrawn as by expiration or combustion it became impure.

Now this Utopia is not to be attained if the hall and passages and the staircases be not considered in the general warming of the house—for myself I am much impressed with the economy in heating an interior which comes from first warming the lungs, so to say. The best salvation from the wasteful consumption of fuel, is the withdrawal of the cause of the draughtiness of rooms, arising from the otherwise uncontrollable difference in temperature between the sitting-room and the hall, by the introduction of a good hall fire or other system of warming the entrance-hall and staircase.

With reference to the lighting of rooms, of course, the softest and most agreeable method of lighting is by wax candles; but the expense of this method precludes its general adoption, except in the drawing-rooms and boudoirs of the rich. But there are many candle lamps (with reflectors for reading, and without them for general lighting) which were in common use before the introduction of colza-oil, paraffin, and other lamps. The inconvenience attending the preparing and cleaning of such lamps has, however, lessened their use, and the cheapness and ready application of gas has led to its most general adoption. The brilliancy of its light, too, when once it has been experienced, adds so to the cheerfulness of the house that it has superseded in a great degree every other. But as Dr. Corfield observes, in the little book containing his Cantor lectures, candles, lamps, and gas all help to render the air impure. It is calculated that two sperm candles, or one good oil lamp, render the air about as impure as one man's respiration does, whereas one gas burner will consume as much oxygen and give out as much carbonic acid as five or six men, or even more. This is why it is commonly considered that gas is more injurious than lamps or candles; and so it is, when the quantities of light are not compared; but with the same quantity of light, gas renders the air of a room less impure than either lamps or candles. If, in the dining-room, instead of using five or six gas-burners, as we too often do, without any provision for the escape of the products of combustion, we used forty or fifty sperm candles instead of six or eight, we should have a fairer

comparison between gas and candles. Common sense at once suggests that the products of combustion should be carried away, and the heat generated by the process should be utilised to expedite its removal, and several manufacturers have turned their attention to this desirable end.

Messrs. Strode's sun-burner, used for lighting large assembly-rooms, is conceived on this principle. Thirty or forty or more gas-jets are placed close together under an enamelled iron reflector, from which the heated air is conducted, through the roof or floor, to the exterior. This first tube is enclosed in a second tube forming a jacket a few inches from the first, which is employed to withdraw the expired air of the apartment.

Messrs. Benham and Sons have provided a globe light for use in ordinary apartments, which is very ingenious and effective. The globe is suspended from the ceiling and is open at the top; the suspension rod is a hollow tube into which the glass chimney surrounding the burner conveys the products of combustion, which are carried away through tubes to the exterior or into a chimney flue. A metal jacket surrounds this tube in the thickness of the floor, and the ornamental rose, forming the junction between the pendant and the ceiling, is pierced to allow of the exit of the vitiated air of the apartment. But in addition to this, between the rose and the ceiling is a small space through which fresh air is admitted to feed the light, thus at once adding to its brilliancy and replacing the air withdrawn by the extracting tubes.

Messrs. Richardson, Ellson, and Co. have many ventilating contrivances, and they publish them in a separate catalogue.

A still simpler and less expensive arrangement is Messrs. Faraday and Son's ventilating gas pendant, also exhibited in the Parkes Museum. This pendant is designed to afford a strong concentrated light with means for carrying away the products of combustion. The gas supply pipes are fixed outside the ventilating shaft, which is thus kept clear of obstruction for the purpose of securing a good draught. Screens of opal glass are provided to soften the light and can easily be removed for cleansing. The trumpet-shaped glass, terminating the ventilating shaft, is released by simply pinching the buttons of the spring clip together. The Argand burner is fitted with a lever check to regulate the flame. Horizontal extract tubes connect the upper end of ventilating tube with the chimney flue.

General Franzini has presented to the Parkes Museum his patent globe reflector. This lamp consists of two hemispherical pieces of crystal—one of these is a bottle used to contain filtered water. The other is of opal, in which may be placed gas, oil, electric, or any other light. The light placed between the two crystals is magnified by the water; with the globe is included a conductor to carry off heat, smoke, and smell from the burning light into the water.

The same person has invented what he terms the "Healthy" gas-burner, and presented one to the Museum. It consists of two small burners fixed side by side to secure more perfect combustion, and an increased amount of light, from a given quantity of gas. The two flames blend together in one large flame and give seven times the light, with no greater expenditure of gas and less product from combustion.

CHAPTER VIII.

HEATING AND VENTILATION NECESSARY FOR APPLIED SCIENCE INSTRUCTION BUILDINGS.

In the design of apparatus intended to heat and ventilate buildings destined for the purposes of technical education, a powerful and constant system is essential and should be capable of ventilating both in summer and winter without the assistance of the general heating apparatus ; and in consequence of the delicate and sensitive appliances employed in many experiments, the position of the radiating surfaces and their composition must be taken into consideration. In addition to ordinary room ventilation for the removal of the expired air and gas lighting, special means for the removal of noxious fumes generated in the laboratories for experimental chemistry have to be provided. The description of the means adopted in four of the latest applied science buildings may therefore be useful, namely : the Finsbury Technical College, the Central Institution (South Kensington), the Yorkshire College (Leeds), and the Merchant Venturers' School (Bristol). The Finsbury College is exceedingly compact in plan, while at Kensington the frontage of the Central Institution is over three times that of Finsbury College and the depth is much greater; but both buildings have a solid internal construction, while the Bristol example, though very compact in plan, presents very little solid wall in its interior arrangement for the passage of ventilating flues and shafts. The Yorkshire College is straggling in plan and, on account of the varying heights presented by the section of the several parts, presents difficulties for the arrangement of the apparatus quite different to all the others. Three of these examples, viz. : Finsbury, Kensington, and Bristol have all been calculated on the same basis of temperature and volume of fresh air for ventilation, viz. : 60° Fahr. in the class-rooms, and 55° in the entrances, staircases, and corridors during an external temperature of 25° Fahr. ; with a ventilation equal in volume to 700 cubic feet per person per hour for the class-rooms, and 3000 cubic feet per person per hour in the chemical laboratories and draught-closets. At Leeds these liberal terms could not be attempted because funds were limited, and therefore only 350 cubic feet per person per hour has been adopted as a basis for the class-rooms—the basis for the laboratory being left intact. At Kensington and Leeds the heating apparatus consists of steam radiating chests, while at Finsbury and

Bristol the heating surfaces are high-pressure hot-water tubes, but as each apparatus is distinct in its character, a separate special description is necessary.

FINSBURY TECHNICAL COLLEGE. (See Plates 14 to 17.)

Here, as already stated, the apparatus for heating the building is on the high-pressure principle, and is constructed for warming by means of "propulsion." The heating power is capable of being directed in its effect, solely or chiefly, to those parts of the building in use for the time being; while at the same time the capacity of the apparatus at any moment to suddenly raise the temperature of any portion of the building is notably increased. The heating surfaces (consisting of 13,000 feet run of wrought iron tubing $1\frac{5}{16}$ in diameter) have all been massed in a central hot chamber in the basement (see basement plan), through which fresh air in considerable volume (viz. 750,000 cubic feet per hour), is driven by a Blackman's fan, working silently and making from 250 to 500 revolutions per minute. The fresh air thus propelled is heated in this chamber to a temperature of 102° Fahr. (the heating surfaces or pipes have a mean temperature of 237° Fahr.), and passes along horizontal channels under the basement floor, from which it is distributed over the building and into the several rooms by means of vertical shafts in the walls, in quantities proportionate to the volume of ventilation it is desired to effect, and to the extent of the cooling surface they severally present. As already mentioned, the apparatus is constructed to yield a general temperature of 60° Fahr., while the external air is at 25°, and with the normal power of ventilation. Since, however, this difference of temperature is of but rare occurrence (the mean winter temperature for England being 39° Fahr., or about 14° higher than the accepted base), the heating surfaces have been distributed over two furnaces, of which one or other, or both, may be used as circumstances may dictate. The fan employed is capable of delivering twice the cube of air necessary for winter ventilation, so that in summer the volume delivered into the building can be notably increased. Since in the case of such an apparatus the intake of fresh air is due to mechanical force, the extract has been left to natural means. Flues have been carried up in the walls to the roof of sufficient area to carry off the volumes of air intended for summer ventilation with the velocity arising from the impulse of the fan at the mean summer temperature; and since in the winter the velocity in these flues would be in excess of what was required, the openings into them from the rooms have been provided with closing-gratings, thus providing the means of regulating the egress. The reason for adopting the high-pressure system in preference to any other for the heating is, that by the use of short circuits, and many of them, this apparatus can be constructed to be almost instantaneous in action, attaining its full heat within twenty minutes from the time of lighting the fire, cooling as rapidly also when the fire is extinguished.

As regards the ventilation, it was found in practice that the brick shaft was insufficiently heated by the internal iron smoke-flue; it has not been taken out in this instance, but the ventilation of the main laboratory has been effected by a 2-foot Blackman's fan working directly upon the laboratory flue, and extracting the air through a special shaft formed over it; the downcast shaft from the laboratory being no longer

used. Dr. Armstrong makes the following valuable remarks upon the working of the plan adopted at this College:—

"Our experience has shown that the system adopted here of warming and ventilating the building is on the whole satisfactory; but several defects have been discovered, which are partly inherent in the system and partly faults of construction. The chief merit of the system of propelling fresh air through a heating chamber by a powerful fan is its simplicity, and provided that the flues are so proportioned as to deliver the exact amount of air required to maintain the various rooms at a proper temperature, there should be no difficulty on this score. Although calculated with the aid of Professor Wolpert's elaborate formulæ, we find in practice, by careful test-experiments, that the various flues do not all deliver air at just the rate and of just the temperature which is required for the efficient warming of all the rooms, and in some we are overheated, and in others under-heated. Whether this is due to a misapplication of the formulæ, or to the omission of sufficient allowance for distance, or to the irregularity in the direction or formation of the flues, further experiments will probably reveal. The most serious objection to our Finsbury system arises from the fact that ventilation and warming are inseparable; in other words, if the temperature in any room be sufficiently high, and it is required to introduce more air, this cannot be done by the apparatus without also raising the temperature. It ought to be possible to admit warm and cold air in varying proportions, or, which is the same thing, to increase or diminish the supply of air and at the same time diminish or increase its temperature, so as to ventilate more sufficiently while maintaining the temperature constant.

"Another difficulty arises from the large amount of dust injected into the rooms with the air. This partly arises from the fact that the flues in our case have been 'parged.' The interposition of a screen, sufficiently close to prevent dust being sucked in by the fan, furnishes too great a resistance; we are intending to try the effect of a very fine water-spray. Probably there would be much less dust had the air been taken at a higher level—near the roof, instead of from the basement area and playground.

"Graduating the flues in the manner shown by the plan of the laboratory-floor (Plate 17) has not been altogether satisfactory, and theory evidently does not quite accord with practice; the 'pull,' in fact, instead of being equal throughout gets less and less as the distance from the extract shaft increases, and will need to be experimentally adjusted.

"It was originally proposed to produce the draught in the flues leading from the benches in the chemical laboratory by connecting them with a downcast shaft which, at the basement, joins the main upcast shaft, 120 feet high, within which is a circular iron smoke-shaft 18 inches in diameter. The waste heat from the heating furnaces and the steam-boiler was to produce the necessary draught. This, however, has not been successfully accomplished, and a number of experiments which we have made seem conclusively to establish the inefficiency of the arrangement; we find that whether we allow merely the waste heat from Messrs. Bacon's furnaces, or also that from our large steam-boiler furnace, or even the heat from these two sources, *plus* that from a furnace 18 inches square at the very base of the shaft, to escape into the central cast-iron smoke-flue, there is practically

but little difference in the velocity of the current in the downcast. The explanation would appear to be that the velocity of the current in the iron smoke-shaft is so great that the smoke does not part with its heat with sufficient rapidity to the air in the lower part of the upcast shaft external to it, at the point whereat the downcast is connected. This has led to the interception of laboratory ventilation, and the results which we have obtained with a 2-foot Blackman's fan, in connection with the laboratory flues, leave no doubt in my mind of the ultimate success of my hood arrangement; and in the future, mechanical ventilation will, I believe, unquestionably be the right thing for a chemical laboratory. All we require now to do is to experimentally study the conditions requisite under our system to obtain an even flow in all the flues."

CENTRAL INSTITUTION AT SOUTH KENSINGTON. (See Plates 11 to 13.)

This apparatus, though very similar to that already described, as far as the bases adopted in calculating for difference of temperature, &c., are concerned, is widely different in system and method of application. The southern wing of the building is only partially constructed, and the system adopted has therefore been chosen with a view to its later extension; and although the limits of the present construction might have permitted of the use of a common hot chamber, its future size altogether excluded the adoption of such a means of warming, and even its present size would have rendered necessary an enormous loss of temperature to the hot air passing along the channels, so that it would no longer have been either desirable or economical to adopt such a system of heating. Messrs. Bacon therefore designed and executed a system of steam-heating apparatus with separate hot chambers for each room. These hot chambers are arranged in a row along the basement corridor, and contain the requisite amount of heating surface, consisting of cast-iron ribbed steam chests, jointed together with flanges and bolts with an asbestos ring between by way of packing. Each group is fitted with valves for its exclusion from the rest of the system, and is supplied with fresh air from a pressure chamber extending over the whole corridor, into which the air is driven by a large screw-fan as in the former case. Throttle valves are provided to each cold air downcast, so that the supply can be regulated according to the temperature of the room served, which is indicated by distance thermometers connecting the rooms with the groups of steam chests. The section of the warm air upcast shafts is in every case calculated according to the normal temperature of the warm air escaping from the hot chamber, and the volume of such air which is to be delivered into the rooms. The distributing steam mains are placed overhead in the pressure chamber already described while the condensed water returns to the reserve tank, placed in channels under the floor. The apparatus is provided with pressure reducing valves, limiting to two atmospheres the pressure of the steam escaping from the boilers to the several groups of heating surfaces, while steam-traps on the condensed water returns prevent the waste of steam. The extraction of foul air is in this case also due to natural means; the various upcast shafts being arranged in groups one over the other, concentrated in a common central shaft increasing in size as

it rises. The extraction from the laboratories, &c., is specially provided for by a powerful fan, twice the power normally intended, so that a strong summer ventilation may be readily obtained.

The steam-heating system adopted here is as nearly a success as can be expected from the forcing principle. The complaints which have been made of the inequality of the heat supplied to various rooms chiefly arose from the want of special supervision, and from the inconvenience arising from the distribution of the heating enclosures all over the basement. The same slight tainting of the incoming atmosphere, resulting from its passage through a dusty steam-heater and long air-flues, both horizontal and vertical, is perceptible, although not so objectionable as at Finsbury, because the flues are lined with facing-bricks, and not with ordinary lime-mortar.

At this Central Institution the internal iron smoke-flue has been removed from the main ventilating shaft, the experience gained at Finsbury College proving its comparative inefficiency, and an extract fan has been fixed at the top of the shaft, worked by gearing from the engine in the basement.

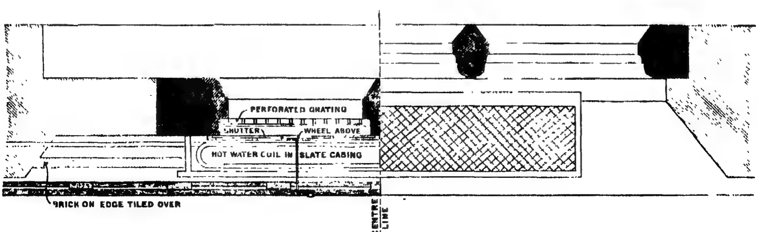
THE YORKSHIRE COLLEGE AT LEEDS. (See Plates 18 and 19.)

The apparatus for warming is by steam-heating chests placed in the rooms themselves, with fresh air passed over them, similarly arranged to the hot-water coils at Bristol. As at Kensington, each group is provided with valves for regulating the temperature; and the pressure of steam in the whole apparatus is limited, by aid of pressure-reducing valves, to two atmospheres.

Professor Thorpe states that the general ventilation of the main laboratory is excellent; and the steam-heating also works well in that room.

THE MERCHANT VENTURERS' SCHOOL AT BRISTOL (See Plates 21 to 24.)

In this building, the necessity for keeping within limits of expenditure dictated by economy, together with the comparatively light nature of the internal construction, precluded the adoption of an indirect heating apparatus and rendered desirable the direct application of



HALF-PLAN THROUGH WINDOW-BACK, SHOWING COIL CASING, &c. — FIG. 1. — HALF-PLAN OF WINDOW-BOARD, SHOWING AIR GRATING.

the high-pressure system, which is more economical in first cost and subsequent maintenance than any other. The heating surfaces are therefore distributed along the external walls in the form of coils, which are placed in the window-backs in slate-lined chambers behind the oak dados (see the two woodcuts); the fresh air being brought in by external gratings through internal regulating valves working in grooves horizontally or vertically as the case may require. On passing into the coil-chambers the fresh air is conducted past horizontal baffle plates over the hot-water pipes entering the rooms in a vertical current at the level of the window-sills; well warmed in winter and cool in summer. The connection pipes between the coils are carried on cast-iron standards projecting 2 inches from the walls over all, and are in all cases arranged for two flows and two returns, which are placed behind the skirting, covered with asbestos cement, so as to heat only by the coils which are all under control. The hot-water pipes are charged with a non-freezing solution which prevents all possibility of accident through frost. The extraction of expired air is effected by mechanical contrivance, and for this purpose all the extract shafts are led downwards to a common collecting horizontal channel under the central corridor of the basement floor. This channel is graduated in size towards the screw-fan actuating the current to the ever increasing volume carried, and the increasing velocity due to the extractor. This extract fan acts not only in the ordinary ventilation, but also in the laboratories and draught-closets, for which therefore in this case no further special means of extract need to be provided, except that the flues are tarred inside. The furnaces for the heating apparatus are two in number, each furnace working, as far as arrangements permit, about half of the surface in each room, so as to allow of one or the other, or both being employed, as the exigencies of the external temperature may demand. By the use of four-way valves any one or more coils may be disconnected.

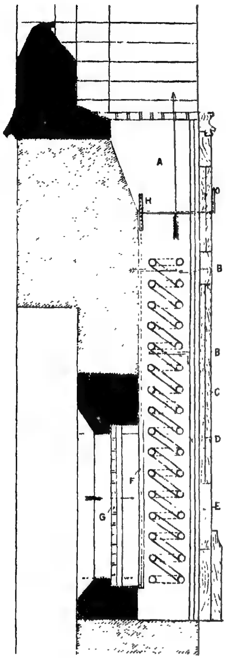


FIG 2. SECTION.[1]

The system adopted by the author at this school differs from the first two systems referred to, because the fresh air is not brought in through long channels and wall-flues, but passes directly from without through the coils situated in the window-backs, as at Leeds. It is only the foul air which is brought through flues by the extracting fan in the basement, an important distinction; but I am disposed to think that it might be an improvement to carry all flues from each floor horizontally to the upcast shaft without a descending flue, as is done at Oldham, and to put the fan at the top instead of the

[1] A. Warm and cold fresh-air chamber; B. Baffle plates; C. Wrought-iron coils; D. Slate casing; E. Oak panelling; F. Shutter; G. Fresh-air inlet; H. Wheel for opening and closing shutter (Bristol example).—E. C. R.

bottom of the extract shaft, as at Munich and Geneva. However, the result of the system at work at Bristol is as successful as any I have examined elsewhere, as may be seen by comparing the actual results obtained with those intended, which are given in the accompanying tables. These tables will serve as a practical example of the application of theory and practice, and an exposition of the sort of calculations involved in scientific heating and ventilation. Moreover, they are based on those prepared for the school, prior to the execution of the works; and when the building was completed they were tested with the results there given. Thus, whereas 1,350,184 cubic feet of air per hour were proposed to be extracted, 1,653,458 cubic feet per hour are actually withdrawn. From the Great Hall 350,000 cubic feet were intended to be extracted in the hour, and 331,500 cubic feet were extracted at the time of the test. From each of the first seven class-rooms in the table it was designed to extract 35,000 cubic feet per hour, whereas an average of 45,000 cubic feet is actually withdrawn, which is equivalent to changing the air $5\frac{1}{2}$ times in the hour. The chemical laboratory had an allowance of 3000 cubic feet of air per person per hour, and was designed to have 120,000 cubic feet of air changed in the hour; as a matter of fact, however, the number of feet extracted within the hour has reached 158,156 cubic feet.

It is very desirable that similar tables should be compiled elsewhere. It is so rare a thing that any system is fairly tested throughout to ascertain the exact results obtained, and how far they correspond with the theoretical quantity of ventilation required.

The temperature of the Great Hall at Bristol, within which the crowded opening meeting was held in the height of summer, was considerably below the external atmosphere, and the variations of temperature within the hall did not exceed 1° Fahr. during the protracted meeting, nor did it rise at any time above 71° Fahr.

In this school each room is separately heated and ventilated, and is entirely under the control of the master; for observe, each coil may be separately cut off from the general circulation without intercepting the flow elsewhere, or it may be partially opened as the temperature may demand, by turning on the three way stop-cocks provided, more or less fully.

The manner in which the temperature is regulated is defective in one respect. Each master has a key, by which he can open and shut any one or more of the coils, and also the fresh-air inlets, at pleasure. And as they sometimes change rooms, one master may, and often does, quite unintentionally leave a room in a condition that might be disagreeable to another. For example, suppose a master goes into a class-room at 10 a.m. and leaves at 11 a.m.; he might find the room on entering at say 55° Fahr., and instead of waiting for the boys to come in, which would cause the temperature to rise to 60° Fahr, he turns on all the coils This might not make the room uncomfortably warm until he was about to leave, but the next master would come into a room with a temperature of 65° Fahr., and rapidly rising. Supposing he turns off the coils immediately, the temperature would nevertheless continue to rise till approaching 70° Fahr. before the coils would be sufficiently cooled down, and at this temperature the air in the room would be very much more foul than it would have been at 60° Fahr., because every one would perspire.

I think these considerations conclusively prove the desirability of putting the heating apparatus under the control of *one man* responsible to the head-master. No system will work automatically or without careful supervision by a competent caretaker.

In the following table, No. 1, the actual temperatures obtained are given.

TABLE No. 1.

Temperatures taken March 18th, 1887.

	9 A.M.	11 A.M.	Remarks.	12 noon.	Remarks.	1 P.M.	Remarks.	Stipulated Temperature.
	Deg.	Deg.		Deg.		Deg.		Deg.
Outside Temperature	34	36	... ...	37	... ...	39		
Class Room No. 1 ...	55	61	Coils on and external air inlets open	60	Coil off, windows open during change of class	64	Windows open at 2 30 ...	65
" " 2 ...	51	57	" " "	55	Windows been opened ...	61	" " ...	65
" " 3 ...	51	56	" " "	55	" " ...	61	" " ...	65
" " 4 ...	50	56	" " "	58	Coils off and windows been opened	60	" " ...	65
" " 5 ...	57	62	Windows open	62	" " "	66	Coil off, window been open ...	65
" " 6 ...	58	59	Windows open during change of classes	60	" " "	64	Coil off, window open ...	65
" " 7 ...	61	61	" " "	62	" " "	67	" " ...	65
" " 8 ...	56	57	Inlets open	60	Door wide open	63	Door wide open	65
Engineering Lecture Room	56	64	One coil off, inlets open ...	65	Both coils off	65	Coils off, inlets open	60
Drawing School	52	55	Inlets open	58	Inlets open	63	Inlets open	65
Second portion of ditto ...	53	57		58		62		
Art Room...	53	54	Hot air gratings covered with clay models	56	Gratings covered	59	Gratings covered	
Metallurgical Laboratory	58	58	Inlets open	62	Inlets and door open ...	60	Inlets open	65
Physical Laboratory ...	55	62	"	64	Coils off	64	Coils off	65
Physical Lecture Room ...	57	64	Coils off, windows open ...	64	Coils all off, four sashes open	64	Coils off, four sashes open ...	60
Chemical Lecture Room...	58	61	Inlets open	61	Coils off, windows and doors open	61	Sashes been open for 30 min.	60
Preparation Room ...	56	58	"	59	Inlets open	62	Inlets open	65
Private Laboratory ...	55	56	"	58	"	61	"	65
Gas Analysis Room ...	55	57	"	59	"	62	"	65
Chemical Laboratory ...	51	60	"	64	Coils all off, door open ...	60	Coils off, doors and four sashes open	65
Balance Room	60	54	Coils off, window open ...	54	Window open	58	Window open...	65

This table of temperatures shows the way in which the apparatus is used by the different masters to suit their own requirements, from which it obvious that the power of the apparatus when windows are closed is equal to the maintenance of the stipulated temperatures given in the last column.
The fires were not lit till 7 a.m. on the day of testing. The usual time for stoking is 6 a.m.

In Table No. 2 the ventilation is given, the velocities are calculated in accordance with the example of Class Room No. 7.

EXAMPLE.

Class Room No. 7.

In this room there are two extract gratings; the dial of the anemometer registers the velocity of the air extracted, which has to be corrected by the addition of the number of feet of air that pass too slowly through the machine to get registered at all. There is a difference of velocity between the forward and backward use of the instrument owing to the obstruction of the arm supporting the axis of the fan, thus 30 is the correction to be added for the forward and 40 for the backward application.

Furthermore, for the same reason, a loss of 10 per cent. on the whole has to be added to the backward reading, as determined by special experiment made for the Author by the inventor of the anemometer, Mr. Lowne, of Finchley.

Extract opening No. 1 measures 25 in. by 6¾ in., equalling 1·2 square feet, see Table No. 2 for the anemometer reading, which gives a velocity of 275 feet per minute; as the air passed through the anemometer the backward way, 10 per cent. must be added to this, and the fixed correction of 40—therefore, the actual velocity is 343 feet per minute. The

area of opening, 1·2 square feet, multiplied by the velocity 343, gives the amount of air actually passed as 411·6 cubic feet per minute or 24,696 cubic feet per hour.

Extract opening No. 2 measures 10 in. by 9¼ in., equalling ·64 square feet; the anemometer reading gives a velocity of 509, to which has to be added 10 per cent. and the fixed correction of 40, making the actual velocity 600, which, multiplied by the area of the grating, gives 384 cubic feet per minute or 23,040 per hour. This result, added to the former, makes a total of 47,736 cubic feet extracted per hour from Class Room No. 7, which is equivalent to changing the air of the room nearly 6 times in the hour.

TABLE No. 2.

Ventilation Report, from tests taken on 18th, 19th, and 21st March.

Name of Room.	Size of Extract Opening.	Area of Extract Opening in sq. ft.	Velocity Anemometer Reading.	Actual Velocity.	Cubic feet of air extracted per hour.	Cubic feet of air required to be extracted per hour.
	in. in.					
Dining Hall	10½ × 3¼	·42	918	1050		
	20 × 6¼	1·0	671	778	83,410 }	140,000 divided into two rooms
Class Room No. 9	17 × 14	1·7	519	611	62,322 }	
" " 1	10½ × 9¼	·7	466	553		
	25 × 6¼	1·2	297	367	49,650	35,000
" " 2	10 × 7½	·52	342	416		
	25¼ × 6¼	1·2	297	367	40,339	35,000
" " 3	15 × 8¼	·86	315	387		
	10¼ × 8¼	·65	421	503	39,580	35,000
" " 4	14¼ × 14¼	1·1	240	304		
	10¼ × 8¼	·6	335	408	40,751	35,000
" " 5	25 × 7¼	1·3	248	313		
	10½ × 9¼	·7	557	653	51,840	35,000
" " 6	25 × 7¼	1·3	332	405		
	10½ × 7¼	·55	354	430	45,780	35,000
" " 7	25 × 6¼	1·2	275	343		
	10 × 9¼	·64	509	600	47,736	35,000
" " 8	3¼ × 3¼	·1	111	188		
	3¼ × 3¼	·1	136	190		
	3¼ × 3¼	·1	137	191		
	4 × 4	·11	263	330		
	10 × 9	·62	167	224	13,025	10,500
Library	17¼ × 8¼	1·0	172	229		
	10¼ × 9	·67	202	262	24,273	16,500
Masters' Room	16¼ × 10¼	·77	102	152		
	15¼ × 7½	·8	243	307	21,750	9,660
Museum	23¼ × 13	2·1	148	203	25,578	24,300
Engineering Lecture Room	26 × 13¼	2·5	52	97		
	15 × 8¼	1·0	89	138		
	20 × 13¾	2·5	64	110		
	15¼ × 8¼	1·0	59	105	45,030	42,000
Drawing School	15 × 13¼	1·5	128	181		
	25 × 10	1·7	247	312		
	10¼ × 20¼	2·8	88	137		
	22¼ × 10¼	1·6	163	220	92,250	56,000
Art Room	10¼ × 13¼	2·0	264	330		
	22¼ × 14	2·2	518	610	120,120	46,920
Metallurgical Room ...	7 × 3	·15	506	597		
	17¼ × 10¼	1·3	262	328		
	10¼ × 4¼	·36	150	205		
	10¼ × 4¼	·36	150	205		
	21¼ × 6¼	1·0	376	454	67,053	28,416
Physical Science Laboratory	4 × 4	·11	356	432		
	17¼ × 11¼	1·5	292	361	35,341	37,120
Physical Science Lecture Room	18¼ × 18	2·3	96	146		
	18 × 18	2·3	102	152	41,124	84,000
Chemical Lecture Room ...	4 × 4	·11	270	337		
	4 × 4	·11	292	361		
Chemical Lecture Room (continued).	4 × 4	·11	310	381		
	4 × 4	·11	266	333		
	33⅞ × 14	3·3	88	137		
	33⅞ × 14⅜	3·3	75	123	60,799	84,000
Preparation Room	18¼ × 10	1·3	184	242		
	8¾ × 7¼	·44	197	257		
	7 × 3	·15	162	218	27,623	22,680
Private Laboratory ...	18¼ × 17	2·2	51	96		
	22 × 2¼	·38	126	179	16,753 }	
Gas Analysis Room ...	10 × 9¼	·64	170	227		21,120
	20¼ × 13	1·9	170	227	34,595 }	
Combustion Room	27 × 8¾	1·7	293	362		
	7 × 3	·15	690	799		
	7 × 3	·15	397	477		
	7 × 2⅞	·15	947	1080	57,948	11,968
Chemical Laboratory ...	27¼ × 8¼	1·7	54	100		
	27¼ × 8¼	1·7	73	120		
	28 × 9¼	1·9	186	245		
	27¼ × 8¼	1·7	205	266		
	13 × 9	·81	42	86		
	4 × 4	·11	349	424		
	10 × 9¼	·66	118	170		
	4 × 4	·11	434	517		
	10 × 7¼	·52	220	282		
	7 × 3	·15	445	530		
	4 × 4	·11	472	560		
	4 × 4	·11	328	401		
	4 × 4	·11	412	493		
	4 × 4	·11	512	603		
	4 × 4	·11	482	570		
	4 × 4	·11	490	579		
	4½ × 4	·13	550	645		
	4 × 4	·11	506	597		
	4 × 4	·11	476	564		
	4 × 4	·11	440	524		
	4 × 4	·11	336	410		
	4 × 4	·11	406	487		
	4 × 4	·11	258	324		
	4 × 4	·11	258	324		
	4 × 4	·11	302	372	158,156	120,000
Small Waiting Room ...	17 × 5¼	·65	114	165		
	15¼ × 6¾	·73	208	269	18,217	Nil
Total					1,321,958	1,000,184
Great Hall, from a previous test, to be added					331,500	350,000
Grand Total					1,653,158	1,350,184

CHEMICAL LABORATORY VENTILATION.

In applied science buildings we have not only to deal with the close atmosphere arising from the congregation of many persons in one room at one time, and for a long time together, but we have also to contend against the obnoxious smells caused by the

experiments carried on in the various laboratories. The removal of these fumes with the greatest rapidity and certainty is best accomplished where the current of air in the extracting shafts of the ordinary room ventilation is in the same direction as that of the draught-closets on the benches or around the walls. This is so obvious when thus plainly put, that it will hardly be credited that in the majority of cases the reverse is the practical fact, thus necessitating the closing of the extract gratings for the ordinary room ventilation. that they may not pull against the extracts from the operating-benches and draught-closets.

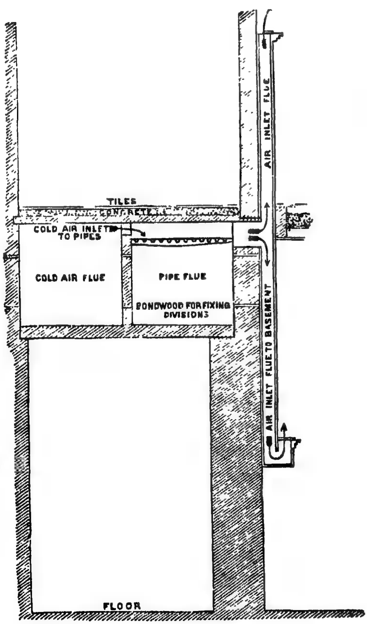
The velocity at which the extraction of air should take place in the draught-closets is not less than 5 feet per second. To ensure this draught at a constant velocity, it is necessary to be independent of casual winds and changing temperature as a means of motion. This requires the employment of certain apparatus to produce either a propelling or a sucking force, of which the latter is usually either a common upcast shaft, heated at its base by a furnace, or the product of furnaces, attached to engines or heating apparatus. Neither of these, however, can be depended on for constancy, and therefore the best agency is a fan; the rotation of which, propelled by a steam, gas, or electric engine, where water power is not available, steadily exhausts the air from the air-channels and establishes an upward and outward current in the shaft from the point at which it debouches. The position in which this extract fan is placed in the shaft, determines whether the vertical warm-air channels shall have an ascending or descending current established within them before reaching the shaft. If placed below the basement and at the foot of the shaft, the current will be descending—if placed at the roof level the current will be ascending—to communicate in each case with horizontal channels, graduated in size, till they reach the spot where the fan is situated.

In many cases on the Continent there are fans both above and below, as at Geneva; in others above for the draught closets only, and a furnace below for the room ventilation. This is the case at Munich, for example, with the result I have already mentioned, but I should explain, that fresh air is separately admitted to the draught-closets as well as the room, and it was thought that this would overcome the difficulty, but it does not in practice, and we should take warning. Of course it is apparent that the extraction of so much bad air must be replaced by a corresponding amount of fresh air, warmed on its entrance in winter, and cold in summer, the only way I know of to prevent cross draughts is to introduce this fresh air with an upward current through vertical shafts, or openings not fixed in the faces of the side walls; then whether you force the air in by fans or leave it to come in as it is drawn, its tendency is to rise before mingling with the air of the room; it is so arranged at Bristol and at Dundee. In summer the room openings for the escape of the foul air may be at the top of the opposite wall, but in winter, if they are not also provided at the bottom of the room, so that the upper can be closed, the warm air will be carried away before warming the room; in either case the air will be pure, because it will never have time to get stagnant, but will always be changing as many times in the hour as may be predetermined.

Between the operating-benches and draught-closets, and the extracting shafts, there are horizontal foul-air channels of communication over or under the floors. At Finsbury the channels were arranged very carefully by Dr. Armstrong, and the sizes were calculated by Messrs. Bacon and Co., and the plan which illustrates them gives also the exact graduated width, the depth being the same throughout, set in a layer of concrete 8 inches thick over the fire-proof floor of the laboratory, lined with Portland cement and pitched inside

and covered with plate-glass puttied in, over which are the iron cover plates which are flush with the floor. At Finsbury the wastes from the sinks are carried into similar channels to the out-fall pipe; and as at Munich and Strasburg there are other channels for gas and water piping, these channels, of course, have no glass covers like the foul-air extract flue channels; the foreign examples are lined with asphalte. There are other horizontal channels at Finsbury which are above the level of the floor, and are formed of dove-tailed wood pitched inside. At the Merchant Venturers' School, Bristol, the air-channels are of wood pitched inside, and with slight variations are all arranged under the floors, in the manner shown in the drawings of the topmost floor of that building, giving the arrangement of the rooms, the fittings, flues, and waste water pipes.

In the Finsbury College, the general ventilation of the chemical laboratories is effected by the bench draught flues, to prevent any counter-action by subsidiary extract shafts. These bench flues have their openings about 5 feet from the floor, and are covered with sheet-iron and glass hoods. Their exact form, and the details of their appurtenances, were decided by Professor Armstrong after a series of exhaustive practical experiments; each flue is in direct communication with horizontal channels running underneath the floor, radiating from the ventilating shaft. In the case of the four schools described, the areas of the flues and channels were carefully calculated by the aid of Professor Wolperts' elaborate formulæ, at every juncture, with reference to the probable velocity to be attained, and the quantity of air to be carried per second. The cost of the apparatus, exclusive of the bench and floor and wall flues, the mason and carpenters' work and painting, amounted to 4000*l.* for Kensington, and about 2000*l.* each for the other three buildings.

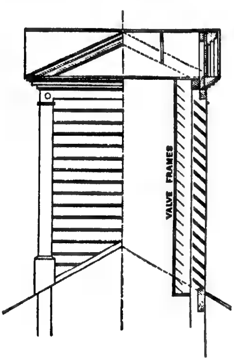


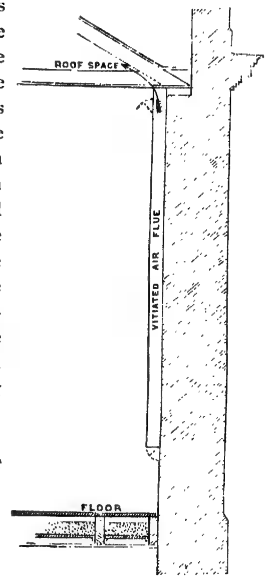
The application of this principle of forcing in air, and leaving it to find its way of escape by any outlets designed or undesigned that may exist, has been applied to the new Chemical Laboratory at Dundee. There the mode of ventilation is known as Cunningham's, and the heating is by Perkins's system of wrought-iron piping at high pressure. The machine-chamber, situated in the basement floor, is a large room, and contains five of Cunningham's air-pumps driven by a two-horse power Otto gas-engine. The fresh air is taken in by two inlet shafts at the back of the building, carried up almost to the height of the eaves, the upper portions being louvre-boarded. The pipes and air flues are placed as far as possible under the ground-floor corridor, and are 3 feet square, but those

under the laboratory and lecture-theatre are 3 feet deep and 4 feet 9 inches wide, and all the air flues have openings into the machine-room. There are twelve pipes abreast in the 3 feet and twenty-four pipes in the 4 feet 9 inches flues. The pipes are placed at 6 inches from the top of flues, and are supported on notched cast-iron brackets. There are two furnaces employed in heating; the pipes from No. 1 are taken in one direction through the flues, and the pipes from No. 2 in

SECTION OF AIR INLET FLUE IN ROOMS

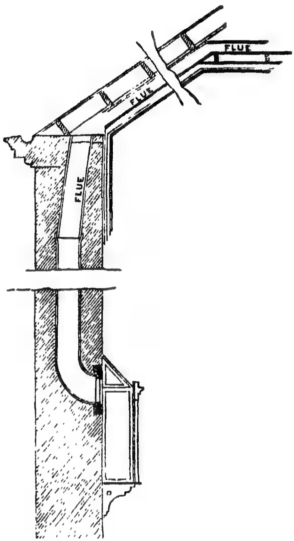
another, so as to have the flues equally heated. When the weather is mild one furnace only may be used. The flues are formed of brick with concrete bottom, and covered with pavement-flags jointed in cement. The air flues in all cases run alongside the pipe flues, and openings are left in these at stated places for the air to pass over the pipes. The pipe flues have also close divisions to regulate the number of feet of piping according to the size of the room to be heated. The heated air from the pipe flues is admitted by upright inlet flues placed on the walls of the rooms, and these discharge the air 5 feet from the floor in an upward direction. These flues are made very flat in order to diffuse the air well and prevent draughts. The insides of the whole of these upright flues, and all the close divisions and other woodwork in the pipe flues have been thoroughly painted with asbestos paint. Wire-netting half-inch mesh, has been placed over the mouths of all the inlet flues.[2] The *extract* flues are placed generally on the opposite side of the room to the inlet flues; they are also constructed of wood, and





[2] Sir Frederick Bramwell has remarked that architects, as a rule, think more of extracting the foul air than of supplying fresh air, and are satisfied with making holes in the roof for its exit and none for its entry; whereas he himself would reverse that operation, and provide for the inlet of fresh air, leaving to its own sweet will the manner of its escape. In all the examples referred to in the present Chapter the architects have considered the introduction of fresh air as, at least, of equal importance to the extraction of the foul air. I may also refer to the system successfully applied by me to the meeting-room of the Society of Arts, with the approval of Sir Frederick, which earned for me the formal thanks of the Council when the late Sir William Siemens was Chairman. Here the fresh air enters by five inlets, and, passing over warmed piping, is admitted through an iron grating 6 inches deep, extending the whole length of the north, and part of the east side of the hall, at about 10 feet from the floor. Moveable horsehair screens are placed at the inlets, to filter out the impurities in the air which might otherwise damage James Barry's pictures. A coil of hot-water pipes, situated in a shaft above the level of the ceiling, extracts the foul air through the openings in the ceiling by means of zinc connecting channels, assisted by the central sun-burner.—E. C. R.

are placed on the walls and are of equal area to the inlet flues in the rooms. These flues come to within 2 feet of the floor, and have a valve on the bottom which can be closed when required; they have also valves near the ceiling which are only used in summer. The air from these flues is led into larger flues formed in the roof space, which are connected to louvre-boarded ventilators placed on the ridge of roofs. These ventilators have valve frames placed about 6 inches from the inside of the louvre-boards, and are formed into squares of about 4 inches. Each square has a valve or flap of indiarubber cloth, which shuts when the wind blows against it, while the opposite side from the wind opens. The area of the openings in each side of these roof-ventilators is equal to the area of the whole of the exhaust flues connected with it, so that when two sides are closed by the wind the other two allow the vitiated air to escape. The whole of the evaporation niches, stink hoods and closets of students' tables in the building are connected to the large air flues in the roof space by fire-clay pipes built into the walls, and by lead flues from the wall heads to the flues in the roof. The draught from these different places is found to be excellent. The quantity of air forced into each room is calculated to renew the whole air in the room at least every twenty minutes. There is a horizontal flue under the floor of the laboratory to which the whole of the descending flues from the students' working-tables are connected. There is no fan connected with the discharge of the air. The air is forced into the rooms, and being always under pressure finds its way out at the openings provided for it; in no case does the area of the exhaust openings exceed the area of the inlet flues. In the students' laboratory the valves of the exhaust ventilators can be closed, which has the effect of increasing the current in the draught-closets, &c. It is obvious, however, that the removal of this pressure of the incoming air by the opening of windows is inconvenient in summer-time, but this can be overcome by introducing air under pressure into the extract flues of the draught-closets.[3]



An interesting discussion took place at the Institution of Civil Engineers in November, 1882, on the reading of a Paper by the late Robert Briggs, on "American practice in warming buildings by steam," to which I must refer the reader. The following description of the mode by which the meeting-room of the Institution of Civil Engineers is warmed and ventilated will be interesting, as giving an example applicable not only to the large lecture-halls of science schools, but even to laboratories; the particulars have been supplied to me by Mr. Phipson, of 14, John Street, Adelphi, by whom the work was designed and executed. It should be noted that, had not the architect, Mr. Thomas Henry Wyatt, sacrificed some of the space in the lower rooms, the result mentioned by Sir Frederick

[3] See Note on page 240.

Bramwell would not have been obtained. Mr. Phipson's experience has convinced him that failures in ventilating arrangements can in many cases be traced to the want of sufficient area in the inlet shafts. The fan which propels the air is worked by a Ramsbottom patent water-engine, driven direct off the high pressure water main. The air shafts leading from the fan are so arranged that, by working a valve, the air propelled and forced into the building can be either passed through the heating-chamber containing coils of hot-water pipes, or direct up the air shafts to the meeting-room. On a level with the meeting-room floor a secondary or distributing chamber is formed by utilising the space under the raised platform of the rising seats, and the air from the fan being distributed on the three sides of it. The perforations from this chamber are calculated to supply a volume of air to the meeting-room equal to six times its cubic contents in the hour, diffused at a velocity not exceeding 6 inches per second. No special means for carrying away the vitiated air are provided except the usual outer shafts around the sun-burners that light the room, the area of these outlets being much less than that of the inlets. By this it will be perceived that the principle adopted is to ensure a supply of fresh air equally diffused, that any stagnation of vitiated air is improbable, for though the outlets around the sun-burners are not equal in area to the inlets, the pressure maintained ensures an outlet at other points, and thus prevents any local inlet currents of air from the exterior of the meeting-room.

At the Oldham School of Science (see Plate 53), the principle adopted is a low-pressure hot-water apparatus for heating combined with direct supplies of fresh air for ventilation diffused through the heating coils, and also through vertical inlet shafts. The aggregate area of these inlets for each room being calculated for a diffusion of the air at a velocity of 2 feet per second.

In the wall of the main staircase a powerful upcast shaft is constructed, the smoke from the hot-water boiler being carried up same in an iron-flue pipe, 18 inches in diameter.

In addition to the heat thus generated inside this shaft, a powerful coil of 2-inch pipes is also fixed, so that in all seasons of the year a difference of 20° Fahr. is ensured between the internal temperature of the shaft and the rooms to be ventilated; a velocity of 4 feet per second is thus kept up through all the extraction flues, and a renewal of the atmosphere of every room four times in the hour obtained.

The apparatus is worked by a vertical hot-water boiler, with top and side feed, and the whole was erected by Mr. Phipson, Heating and Ventilating Engineer, 14, John Street, Adelphi, London.

I conclude this chapter with a comparative description of the various systems of heating and the various formulæ in use, by which their relative effectiveness and economy is arrived at; it was prepared for me by Mr. A. J. Bacon, of Antwerp, and is an interesting study.

Deperdition of Heat.

"Before describing individual systems of heating apparatus, a glance may be taken at the basis of calculation on which such apparatus must be constructed. It may be premised

that scientists, in order to define given quantities of heat, have assumed as their unit of measure the specific heat of water—i.e. the amount of heat necessary to raise 1 lb. of water 1° Fahr. in temperature—and that they express all other quantities in terms of this measure. The specific heat varies with the class of material acted upon. Thus, the specific heat of air is 0·238 units, or about a quarter that of water. Another point that must be remarked, before entering further on this part of the subject, is the conducting power of heat that materials possess in various degrees, and which plays a considerable *rôle* in making such calculations. Thus, the heat, in terms of units, transmitted per hour for a difference of 1° Fahr. in temperature through a surface 1 in. in thickness is :—

For marble	28·0	For plaster	3·86
„ ordinary stone	13·68	„ oak—perpend to fibres	1·70
„ glass	6·6	„ fir	0·83
„ brickwork	4·83	„ paper	0·346

Hence it is evident that the amount of warmth lost by a room or building, heated above the external temperature, varies with the nature of the building material and the quantity used. By the aid of the above and other data, which it would take too long to explain, Mr. Box has constructed the following table, which may be useful :—

Loss per Hour for 1° difference of Temperature.

Brick Wall.		Stone Wall.	
Thick.	Units.	Thick.	Units.
4½″	0·371	6″	0·453
9″	·0275	12″	0·379
14″	0·213	18″	0·324
18″	0·182	24″	0·284
27″	0·136	30″	0·257
36″	0·108	36″	0·228

The co-efficient for ordinary window-glass is 0·53, and for double glass 0·27 units.

An examination of the above tables will at once show that an architect, by careful choice of his building materials, can himself do much towards economising the expense of heating hereafter—it being patent that the use of good brickwork in place of stone, of double windows instead of single, of thick or hollow walls instead of thin or solid, is always of ulterior advantage and economy. The above tables will serve to determine roughly the amount of heat lost per hour under fixed conditions of temperature, though in practice several other factors, such as height, aspect, and number of external faces, would have to be taken into consideration. The probable frequency of use would also require to be taken into account: thus it is evident that where a building is used only occasionally—a church, for example—it is useless putting in a heating apparatus only sufficiently powerful to make good the hourly deperdition of heat, whereas, in turn, this might be amply sufficient in the case of a hospital or similar building, where the fire is constantly kept going.

Having determined the amount of heat necessary for the loss per the walls, &c., that required for the air introduced for ventilation must be ascertained. This can be done roughly by the aid of the formula :—

$$(1) \quad 0{\cdot}01817\, n\, (T - t)$$

Where n = ventilation in cubic feet per hour
" T = internal temperature
" t = external temperature
" $0{\cdot}01817$ = specific heat of a cubic foot of air at 32°.

This formula, however, does not give exact results, because the specific heat of air when considered in volume varies with the temperature as its density. It is therefore usual in practice to reduce volumes of air to weight in pounds, when the specific heat is practically constant at 0·238 units. The total thus obtained, added to that previously calculated for the deperdition, is the amount of heat the heating surfaces must yield per hour, and their surface can then be readily deduced.

Artificial Heating Apparatus can be divided into five chief classes—viz. radiating fires, hot-air stoves, steam, hot-water large-pipe, and hot-water small-pipe apparatus. The first of these has already been considered by Mr. Robins.

Hot-Air Apparatus.—These are innumerable in shape and arrangement, some of good, some of bad construction. Their chief advantage is that great quantities of air can be produced at high temperatures, with a minimum of space occupied. They are, however, of practically little service where ventilation is desired, inasmuch as they deteriorate the air they introduce, by over-heating and tainting. They are, however, very economical in first cost, when not coupled with an extended system of brick flues, but should not be introduced into buildings with roofs of different pitch, such as Gothic churches, &c., because the air will not properly circulate, and the effect is unequal. They should always be constructed so as to draw their supply of fresh air direct from the outer atmosphere, and not, as they frequently do, from the building itself. Great care should be used not to let the flues be in contact with any woodwork, as they are then highly dangerous. At Christ Church, Battersea, when such an apparatus was taken out, by the advice of the architect, Mr. Robins, the floor of the vestry under which the stove stood was found to be charred on the under side, to a depth of half an inch. On the Continent these apparatus are daily growing in disfavour, new constructions being, for hygienic reasons, generally provided with some system of heating employing surfaces at lower temperature. The heat given off per square foot of hot-air stove surface varies from 1500 to 4000 units per hour.

To calculate the surface of such an apparatus the temperature of the air at its outlet must be determined (not higher than 100° Fahr.), and, the deperdition per hour being previously ascertained by calculation, the internal and external temperature fixed, the amount of air necessary for introduction must be evolved by the formula :—

$$(2) \quad n = \frac{d}{0{\cdot}01817\, (T - t^1)}$$

Then, assuming 1 □ ft. of heating surface = 2750 units, the necessary surface will be :—

$$(3) \quad S = \frac{{\cdot}01817\, n\, (T - t)}{2750}$$

In cases where the supply of fresh air is drawn from the building itself less surface is necessary, and the formula becomes :—

$$(4) \qquad S = \frac{d}{2750}$$

The consumption of fuel in such apparatus varies so much with their construction, that it is impossible to give any reliable data, though it may be taken :—

$$(5) \qquad \text{At } w = \frac{\cdot 01817\, n\, (T - t)}{5000} \text{ in the one case; or} \qquad (6) \qquad \text{At } w = \frac{d}{5000} \text{ in the other.}$$

d = deperdition in units per hour
n = quantity of air in cubic feet
T = temperature of air on entering room
t^1 = temperature of room
t = temperature of external air
w = weight of gas coke in lbs. per hour.

Steam Heating is specially useful where the distances at which the heat is required from the boiler are very great, the velocity of the heating agent being far superior to any other that can be employed. It is, however, very expensive in combustion of fuel, inasmuch as it passes the water into the return pipe as useless just where a hot-water apparatus commences to flow—viz. at 212°. Roughly speaking, water rises in temperature at the rate of 1 unit per pound and per degree Fahr., until it reaches a temperature of 212°, when it boils. It then takes up 966 units of heat in a latent state in the act of vaporization, or of becoming steam. If under pressure, the temperature at which ebullition commences rises; but the amount of heat necessary to produce steam at any pressure remains practically the same. The calorific value of a pound of steam is nearly the same —viz. 966 units (the latent heat of vaporization), whatever the pressure of the steam employed. The only advantage, therefore, derived from high-pressure steam apparatus is a slight difference in the first cost, on account of a higher mean temperature of the heating surfaces; this advantage is, however, more than counterbalanced by the increased risk of leaky joints and defective tubes. It is usual, therefore, to employ steam at low pressure— say, at 1 atmosphere for the purposes of such apparatus.

Given the quantity of heat necessary for warming and ventilation, and allowing 10 per cent. for loss of heat in mains, the amount of steam required would be :—

S = quantity of steam in pounds per hour
d = heat required for warming and ventilation.

Supposing the feed water to enter the boiler at 60°, the quantity of heat necessary for producing this steam would be :—

$$(8) \qquad \{966 + (212° - 60°)\}\ S = 1118\ S,$$

and the fuel necessary :—

$$(9) \qquad w = \frac{1118\ S}{7500} = \text{weight in pounds of gas coal per hour.}$$

Messrs. Geneste, Herscher and Co., of Paris, have erected steam-heating apparatus, where the main pipes have led away from the boilers, a distance of 1000 mètres, or 3280 ft.,

with perfect effect; and in America, district steam apparatus have been constructed distributing steam for varying purposes at distances over a mile from the boiler.

On the Continent, steam-heating apparatus have been brought to a high state of perfection—tubular boilers built on the Belleville principle are employed for the steam generation; the mains are laid in channels under the roof, covered with non-conducting substance, and branch from thence to the several heating surfaces placed in the rooms below. Each branch is fitted with a pressure-reducing apparatus, and each heating surface is connected with the condensed-water mains fixed in the basement, which lead back to the boiler. Every such connection is fitted with an automatic steam-trap, which opens whenever the water accumulates, and allows the same to pass, closing, however, at once on the arrival of non-condensed steam and thus economising the amount of steam used.

The heating surfaces employed are various, consisting of double-jacketed cylinders, vertical-ribbed tubes, or cast boxes. Messrs. Gebrüder Sülzer, of Winterthür, who have perhaps the greatest name on the Continent for steam apparatus, employ double-jacketed cylinders chiefly, of which the internal hollow space is filled with tubes of small diameter. Messrs. D'Hamelincourt, of Paris, again, employ cast tubes fitted with ribs ranged either longitudinally on the outside of the pipe or transversely, according to circumstances. In Germany, boxes having a surface varying between 2, 3, and 4 □ mètres are employed. The boxes are made with vertical cast ribs, and are used singly or connected together in series, according to the surface required, with flanged joints and asbestos packing. The calorific value of these various forms of surface is 390 units per □ ft. per hour for plain, and 260 units per □ ft. per hour for ribbed, surfaces.

Such apparatus should, however, only be put up by capable persons, and left in the charge of responsible hands. At St. John's Cathedral (Catholic), Salford, a steam apparatus was taken out some years ago, of which the boiler was of single-flued Cornish pattern. The steam pipes, four in number, leading from same passed down the whole length of the nave, and terminated with 1¼″ tubes fitted with a cock (!) for regulating the escape. Fortunately for the congregation, these cocks had never been used, since, when taken out, the boiler was found to have its safety-valve jammed down by means of a block of wood (!!) inserted between it and the arch over.

Large-pipe Hot-water Apparatus.—This, the most common form of heating apparatus in England, is perhaps also the best understood in the country; but, being often put up by persons utterly ignorant of its principles of action, the effect produced is not always satisfactory. This system has the great advantage over all its competitors of retaining its heat for a longer period after the fire is extinct, though of course it also possesses the corresponding disadvantage of requiring the most fuel to attain its effective heating temperature. Properly constructed, it is simple and certain in action, and, if its joints are made on a good principle, should last a long time. The tubes consist generally of cast-iron, fitted with either flange or spigot and socket joints, caulked with red and white lead and yarn. Lately, however, several forms of joints have been introduced, based on the employment of indiarubber rings or slips—such joints being now used generally by Messrs. Haden and Sons, of Trowbridge, and others. The boilers used for this apparatus are legion in pattern, the most common form being that known as the saddle-backed boiler. Tubular and Cornish boilers

are used for larger apparatus. Messrs. Hartley and Sugden, of Halifax, construct a series of very ingeniously designed boilers for this system of apparatus, made of welded plate-iron. Taking the temperature of the pipes on leaving the boiler at 212°, and at the return at 100°, the surfaces would have a calorific value of about 160 units per □ ft. per hour. On account, however, of the large body of water and weight of material in such an apparatus —which has to be raised to the mean heat before it begins to yield its full effect—it is very extravagant of fuel. Thus, taking the mean heat, as above, at 156°, and the temperature of the apparatus before lighting the fire at 40°, the materials have to be raised 116°, and the amount of heat necessary for the several sizes of tube would be per foot run :—

For 2-inch pipe = 288·4 units
" 3-inch pipe = 539·4 "
" 4-inch pipe = 868·8 "

Given the amount of pipe, it is easy with the above data to ascertain the amount of fuel necessary for raising the apparatus to its effective point, the formula being for :—

$$(10) \qquad 2'' \text{ pipe} = \frac{l \times 288{\cdot}4}{6500} = \text{weight in pounds of coke.}$$

l being the length of pipe in feet, and so on.

When once hot, the fuel used would only be :—

$$(11) \qquad \frac{d}{6500} = w = \text{per hour};$$

but, in order to secure such economy, a good stoker is required, since necessarily the grate service of the boiler is calculated for the larger quantity of fuel, and it stands to reason, therefore, that it is seldom attained.

Small-pipe Hot-water Apparatus.—This system, first introduced about fifty years since by Mr. A. M. Perkins, is based on a different principle to the foregoing—namely, on the fact that by the introduction of pressure the phenomena of ebullition are avoided, and water will rise beyond 212° at the rate of 1° per lb. per unit of heat, and that, in consequence, a far smaller diameter of tube can be employed. Allowing for the necessary expansion, owing to increase of heat—but not sufficient to permit of the accumulation of steam—and using a strong wrought-iron pipe, he produced a very useful apparatus, and one that might successfully have beaten all its competitors from the field, had not the principle been carried too far, and the use of too highly heating surfaces produced many of the evil effects for which the hot-air system is so justly disparaged. Conviction has, however, since introduced many improvements in this apparatus, and it can now fairly compete with its fellows. The old form of apparatus was constructed of tubes having an internal diameter of $\frac{5}{8}$ in., which, owing to the friction offered to the circulating water, rendered it impossible to attain an effective heat on the return pipe without the employment of excessive temperatures on the flow. Mr. Bacon, however, in conjunction with Mr. L. Perkins, introduced a larger section of tube—$\frac{7}{8}$ in. diameter—in the year 1864. This improvement rendered it possible to attain a greater equality of temperature at the two extremities of the circulation, and hence obtain the same mean result as formerly without the necessity of excessive heat in any part. This improvement was first introduced in Hamburg, and gave the system a wide

extension in Germany, where it is universally esteemed, and thousands of apparatus have since been erected; it has also revived its adoption in England of late years.

Besides the above, Mr. Bacon has further improved the system in several details, fixing the pressure of working by the use of valves instead of the above-mentioned expansion tubes, carefully regulating the fire-grate and furnace heating surface to the power of the apparatus, and introducing numerous minor improvements.

In 1878, Mr. Stainton introduced another important improvement in the shape of an alkaline solution for charging the apparatus. This overcame the necessity for keeping the fire going in frosty weather (even when not required for heating purposes), as was formerly the case, and thus improved, the apparatus may be universally adopted without fear of any evil result.

This system offers considerable advantages, viz. the rapidity with which the apparatus may be raised to its effective heat, and the small quantity of fuel necessary for doing so; the ease with which it may be adapted to old or new buildings; the simplicity of its management and its freedom from liability for repair. In place of a boiler its furnace contains a coil of precisely the same kind of tube as used for the *heating* surfaces, and since the temperature of this coil is ever increasing throughout its length, from the return to the flow, it is evident that, in a carefully constructed furnace, nearly the whole heat given off by the fuel may be passed into the apparatus. As a matter of fact the heat utilised in these furnaces is greater than that in any other form of boiler, being 90 per cent. of the actual total value of the fuel. The amount of heat required to raise one foot of this pipe to its effective heat is 112·48 units, which, as compared to that required in the case of large-pipe hot-water apparatus for equivalent surfaces, stands in the favourable proportion of 1 : 3·18, while the calorific value of equivalent surfaces of this tube and hot-water tube show the proportions of 1 : 0·6. The apparatus is therefore eminently economical as regards its extension of surface and the fuel it consumes.

Ventilation.—This is a subject in which England stands far behind its sister countries. Architects very frequently neglect the subject entirely, or introduce untried and often impracticable means, with less regard to the result required than to what the design of their building permits. This arises chiefly from their considering the matter only when the construction is so far advanced as to permit of no properly matured scheme; and from their regarding the ventilation as a suitable portion of their programme upon which to exercise the pruning-knife. But since there are no governmental precepts laid down, and the public are not exacting, this oversight is not astonishing.

On the Continent, however, this matter is considered of the very first importance, being usually decided before the commencement of a building, and entered upon at great cost. Nor do architects overlook the importance, even if their clients would do so; for instance, Mr. Baeckelmans, of Antwerp, actually refused to carry out the erection of the town hospital—a building of considerable importance, and for the design of which he had obtained first premium in competition—because the Hospital Commission would not appoint an engineer to consider the plans with him, with regard to the heating and ventilation, before the foundations were laid.

The first point to determine, before planning a scheme of ventilation, is the amount of

fresh air it is necessary to introduce for the purpose, and to assist in this it may be useful to quote various authorities.

Thus Ferrini gives a table which may be of service. Morin gives another in his volume on ventilation; and Wazon, in his "*Rapports sur l'Exposition de* 1878," part VI., p. 209, after quoting the preceding table gives a third—based on his own calculations. The three placed together and converted into cubic feet read thus:—

Species of Building.	Cubic Foot per person per hour. FERRINI.	Cubic Foot per person per hour. MORIN.	Cubic Foot per person per hour. WAZON.	
HOSPITALS:—				
General Wards . .	2450	2100	2100	3970 (Chaumont)
Operation Rooms . .	2700—3500	—	—	—
Infectious Wards . .	5250	—	—	—
PRISONS—By day . .	1750	—	1400	—
,, By night . .	—	—	1050	—
BARRACKS	1400—1750	1400	1050	2970 (Chaumont)
Stables	6300—7000	—	—	—
Ordinary Workshops .	2100	—	—	—
Unhealthy do. . .	3500	2800	2800	—
Concert Rooms—Theatres	1400—1750	1400	1400	—
Assembly Rooms . .	2100	—	—	—
Schools	525—700	420—525	700—1050	—
,, for adults . .	1050—1225	875—1050	1400	—
,, night . . .	1225—1400	—	—	—
Ordinary Dwelling-houses	525—700	—	1400	—
Offices	—	—	—	—

Dr. de Chaumont proposes for ordinary hospitals and barracks a ventilation of or 2975 cubic feet per head per hour, and proposes further that this quantity, which is deduced from chemical experiments, should in the case of hospitals be increased one-third in order to insure a good result. This is quoted by Ferrini in his work, who, however, at the same time, remarks that the figures are excessive and at variance with other results obtained by the same author.

That the quantity of air necessary for ventilation is daily acknowledged to be far greater than was originally supposed is evidenced by the advancing opinions of all authors. Thus Péclet in his second edition of "*Traité de la Chaleur*," fixed $6m^3$ or about 210 cubic feet per person per hour as the maximum necessary for respiration; however, in his third edition he raised this figure to between 245 and 385 cubic feet, while later on, in the same volume, he advises 2100 cubic feet for the ventilation of hospitals; and in his last edition speaks of 3500 cubic feet as necessary for ordinary wards, 7000 for infectious, and 10,500 for lying-in wards.

Authorities being so various, it may be as well to give some idea of what is demanded in practice. In Belgium, for example, the Government requires for all schools a ventilation equal to 700 cubic feet, and for barracks 40^{cm} or 1400 cubic feet per head per hour.[4] For the hospital at Antwerp, 2800 cubic feet per patient per hour, with power to increase to 5250 cubic feet, was demanded in the instructions to competitors for the warming and ventilating apparatus. In the Trocadéro at Paris 1400 cubic feet per person per hour are introduced; the fresh air enters at the ceiling and passes out through 5000 openings in the floor. This work was executed by Messrs. Geneste, Herscher and Co., of Paris, and is very satisfactory. At the Opera House in Vienna, ventilated on Bohm's system, $9000 m^3$ are driven in per hour by means of a fan = to 1050 cubic feet per person per hour; the fresh air is introduced at every level and every point throughout the building, and passed off by the ceiling—the system being a perfect success. In designing a system of ventilation it is necessary, after determining the quantity of air required, to fix the principle on which it is to be introduced and warmed. Of these there are several:—

a, Ventilation by warm air drawn or driven from a common hot chamber.
b, id. id. id. from separate hot chambers.
c, id. by cold air passed over hot surfaces in the rooms themselves.

In the case (*a*) it is impossible previously to fix the quantity of air if the temperature is determined, because, as the air is heated to a common temperature, a sufficient quantity must be admitted, so that escaping by the exit openings, at the normal temperature of the room, it leaves in its passage the amount of heat necessary to make up for the deperdition per the walls, &c.

To calculate such an apparatus, therefore, the quantities of warm air necessary must be determined by the formulæ used in the case of hot-air apparatus, and when thus fixed, the amount of heating surface must be determined according to the calorific value of the special kind of apparatus employed.

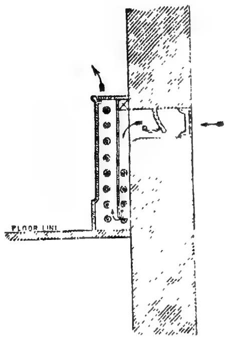
If, however, as in the cases (*b* and *c*), the heating surfaces necessary for each part are separate, the quantity of fresh air may be determined as well as the temperature of the room. Sufficient heating surface is placed in the hot chambers so as to deliver the air at such a higher temperature, that after replacing the deperdition per the walls it passes off, at the normal temperature, by the exit opening.

In this manner the great hall of Mr. Robins's Sandall Road Schools is heated. The heating surfaces are placed in vertical shafts in shape of six coils, each containing 100 feet run of small hot-water tube, the shafts are 14 in. by 18 in., and the height from floor of chamber to exit opening is 14 feet. The fresh air for these hot chambers is led along horizontal channels under the basement-floor, being temperated slightly in its passage by the connection tubes leading to the coils. When at work the hall attains a temperature of 55° easily, with a freezing temperature outside, and a ventilation equal to 106,776 cubic feet or 356 cubic feet per person per hour. Under a difference of 55°—30° the deperdition of this hall is about 31,694 units per hour; the velocity in the shafts varies from 2·5 to 4·7 feet per second, with a mean for the six shafts of 3·3 feet, and the total amount of heat

[4] Since this was written, the amount of fresh air required for schools, by regulation, has been increased to 875 cubic feet per person per hour.

passed up in this air is equal to 60,000 units per hour. The total amount of heat added by the audience = to 300 persons is 300 × 191 = 57,300 units; the total amount of heat in the air is therefore 57,300 + 60,000 = 117,300 units. The hall can therefore be maintained at a temperature of 55° even with an external cold of:—

$$55^\circ - \frac{117300}{\frac{31694}{25} + (106776 \times \cdot 01817)} = 55^\circ - 36.6^\circ = 18.4^\circ$$



The system *c*, namely, that of heating surfaces placed in chambers or boxes in the rooms themselves, has been introduced by Messrs. Bacon in several school buildings on the Continent. The heating surfaces, calculated according to the deperdition of the heat required, and the heat required for the air admitted for ventilation (20^{m^3} per person), are fixed in a cast-iron box, ranged dado fashion along the outer wall, with a grating above to permit the passage of the warmed air. This box is placed in communication with the outer air by means of openings contrived under the windows, fitted with automatic regulating valves which close with any gust of wind, thus:—The air entering at the base of this hot box passes through the same and out by the grating—the difference of temperature attained in the classes being 40° Fahr. despite constant ventilation. Such an apparatus has been erected by the same firm at the Athénée at Tournai, with such satisfactory results that they have since been instructed by the same municipality to heat the theatre and a large girls' school, and have through its recommendation obtained the contract for warming a large school of thirty-five classes in Brussels and another at Couvin.

The action of the various apparatus above described is based on the principle of the air passing up the shafts through its own lightness of weight—the rules for calculating the velocity, where not known, or if known, the temperature in the shaft necessary to attain such velocity, being, according to Wolpert's formulæ (as corrected for English units of measure):—

$$(12) \qquad v = \sqrt{\frac{2 g h (T - t)}{459 + t}}$$

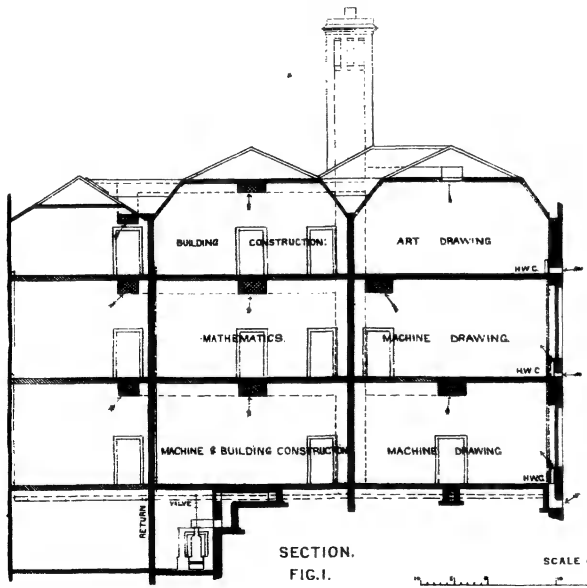
$$(13) \qquad T = t + \frac{v^2}{2 g h}$$

Where v = velocity in feet per second
" h = height of shaft in feet
" t = temperature of room
" T = " of shaft.

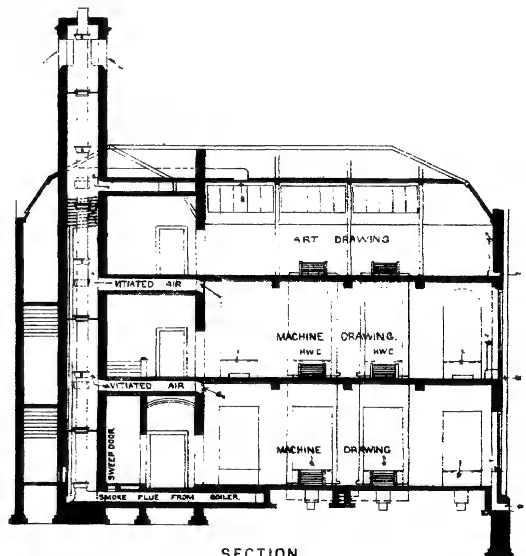
In certain cases, however, it is convenient to substitute mechanical means in order to attain the velocity: for instance, where the ventilation is required both winter and summer, and no difference in temperature can consequently be relied on to actuate the current, or where the amount of air admitted cannot be allowed to fluctuate with the external temperature, or where the quantities of fresh air required are greater than can be conveniently attained

OLDHAM SCHOOL OF SCIENCE AND ART.

HEATING AND VENTILATION BY W. W. PHIPSON.



SECTION.
FIG. I.



SECTION.
FIG. 2.

SCALE OF FEET.

WOODHOUSE & POTTS, ARCHITECTS.

at low velocities. In such cases a fan driven by steam or water or wind power is employed.

Messrs. Verity and Sons have lately brought out a fan of this description, driven by a fine jet of water, which is very useful for small purposes, but the expense of working it prevents its adoption in buildings of importance. In such cases a large fan, driven at slow rate, is more expedient; and where the use of a steam-engine is objected to, a gas-engine on the "Otto" principle may be advantageously employed.

Extract Ventilation.—No system of ventilation is complete unless the extraction of the air is provided for, as well as the inlet, and in equal volumes. To carry off the foul air, shafts should be constructed in the walls, working naturally in the case of inlet ventilation by means of a fan, and artificially where the inlet is provided for by natural means. The best system of extraction in the latter case is a draught-chimney heated by the smoke from the boiler or furnace. The volume of air passing through the shaft being known, the temperature can readily be determined by the formula:—

$$\frac{[illegible]}{2 \times 0{\cdot}238\, w}$$

Where s = surface of flue—and

,, w = the quantity of air to pass over same in lbs. weight per hour

,, t^1 = mean temperature of flue.

T being thus ascertained, it can at once be inserted in formula (12), the velocity found, and the area fixed.

The section of the downcast shafts, leading from the several rooms, should be sufficiently ample to allow of a velocity not exceeding 3 feet per second, and the area of channels connecting these with the upcast shaft can be roughly determined by taking the mean of the velocities of the downcast and upcast shafts together, or $\frac{v+3}{2}$. Care should be taken that these channels flow as directly as possible to the main upcast shaft, and that corners are avoided. The higher the shaft the greater the velocity, and the less heat necessary for the draught. In place of the smoke-flue, heating surfaces of the same nature as the apparatus, gas-burners, or draught-furnaces may be employed, the same formulæ serving in all cases.

In buildings used for public assemblies, such as theatres and concert-rooms, the question of ventilation is abnormal—such buildings requiring absolutely no artificial warmth since the audiences suffice to heat them to suffocation. It is, however, impossible in winter to cool them down without inconvenience by the introduction of fresh air at the external temperature, and the air admitted must therefore be tempered first, and introduced at some point below the normal temperature, say 15°. The volume necessary for ventilation then becomes:—

$$(15) \qquad v = \frac{[illegible]}{{\cdot}01817\,(T - t)}$$

In which a = number of persons in audience

,, d = deperdition at fixed difference of temperature per hour

,, T = temperature of air at entry

,, t = normal temperature of building

,, v = volume of fresh air in cubic feet per hour."

C C 2

CHAPTER IX.

BUILDINGS FOR SECONDARY EDUCATIONAL PURPOSES.

IT has long been the meritorious privilege of the Society of Arts to inaugurate valuable reforms in social and political economy, and to materially aid in the development of educational, industrial, and commercial enterprise. It is there that the enthusiast, charged with some fixed idea as to the particular mode by which improvements may be effected in any time-honoured custom, or antiquated system of doing or thinking, may deliver himself of his crotchet, and bring to the test of discussion the result of his lucubrations. The earnestness and honesty with which opinions may be stated are sure of appreciation there, even though the convictions themselves do not find approval; and therefore it is that any one may feel free to speak his mind without let or hindrance, knowing well that the wheat will be separated from the chaff by the interchange of ideas, and that progress of a more or less substantial character will result from the consideration of the questions at issue.

Upon the subject of Secondary Educational Buildings a variety of opinion has existed, and still exists, and it is no purpose of mine to claim exceptional superiority to, or even exemption from, the weaknesses of others. Nor shall I stay to magnify existing deficiencies, but rather try to add what I may towards the solution of a problem which is every day becoming more interesting as its importance is more keenly felt.

The inconsistency subsisting at the present time, with reference to the supervision and control of educational buildings, is obvious to all whose attention has once been drawn to it. While in elementary schools, workhouses, and lunatic asylums, restrictions are imposed, and rules and regulations are enforced, which prescribe the minimum superficial area and cubical space to be allotted to each inmate, in secondary and higher-class school-buildings no such supervision exists, and the middle and upper class boys and girls of the period are allowed to be packed away in close, ill-ventilated, badly-arranged apartments, without any controlling authority, in premises not originally constructed for educational purposes, and with none of the appliances common to every Board School. A private

This chapter formed the subject of a lecture delivered at the Society of Arts in 1880.

house, originally intended for the accommodation of less than a dozen persons, is seized upon for a middle-class school for several hundred pupils.

Properly certificated teachers are demanded for primary tuition, but any speculative person whether certificated or not, may establish a secondary school; and no Minister of Education may interfere with the glorious independence of the bold Briton who, perchance, may add to his intellectual incapacity entire ignorance of sanitary laws, the consequent effect of which upon the physical and mental vigour of his pupils, however deleterious, passes unchallenged.

Mr. Matthew Arnold has well said:—

"The middle classes in England have every reason not to rest content with their private schools; the State can do a great deal better for them. By giving to schools for these classes a public character, it can bring the instruction in these under a criticism which the knowledge of these classes is not in itself at present able to supply: thus, the middle classes might, by the aid of the State, better their instruction, while still keeping its cost moderate. This in itself would be a gain, but this gain would be nothing in comparison with that of acquiring the sense of belonging to great and honourable seats of learning, and of breathing in their youth the air of the best culture of their nation. This sense would be an educational influence for them of the highest value; it would really augment their self-respect and moral force: it would truly fuse them with the class above, and tend to bring about for them the equality they desire."

How this desirable end may be brought about, it concerns us all to enquire. I can do no more, in the present chapter, than call attention to it, in the hope that it may yet receive the consideration it demands from a patriotic people.

The recent growth of intelligence in the design and construction of national schools, and their appliances, is too obvious to need more than a passing remark, when comparison is made between the latest efforts of the London School Board and the system which preceded it. The effect of this improvement is, however, beginning to be felt in secondary schools; and its influence will be still more marked in the future, as time rolls on, and the necessity for the same constructional advantages is better understood and appreciated. Humble as yet may be the educational results of the London School Board curriculum beyond the three R's, the social and moral influences of its ample provision of space, suitable fittings, and sanitary arrangements, cannot be otherwise than considerable.

The older educational endowments for higher education are associated with buildings erected at a period when sanitary laws were little understood. As Mr. Robson observes:—

"Our old foundation grammar schools furnish us with few ideas as to the future planning of public middle schools; their sole provision was usually a single lofty and noble hall of oblong form, in which the whole of the boys might be seen engaged in their various lessons, learning by 'art,' or carefully plodding with grammar and dictionary within sight of the master, who was placed on a raised platform. No class-room ever, until quite recent years, spoiled the simple dignity of these architecturally excellent school-houses, and their fittings were of the rudest and simplest kind."

Through the action of the Endowment Commissioners, many of these old institutions are being remodelled, and schemes for their wider use and development are constantly being thought out, as new buildings are required to meet the increasing demands for space. Opportunity is thus occasionally given to exercise the ingenuity which has been so well displayed in primary school-houses, on middle-class school buildings.

Private schools in particular, as I have already observed, usually suffer from the disadvantages of being located in houses not specially constructed for them. Public schools will inevitably become more and more popular as the teaching power improves, and as the opportunity for proper classification—which is increased with the larger numbers to be taught in one and the same building—is recognised. Public schools for boys have always been more or less in vogue, but public schools for girls are a modern innovation, calling for special contrivance in the buildings appointed for their use.

Concerning public day-schools for girls, and with respect to their suitability for the purposes contemplated, Miss Wolstenholme emphatically says:—

"The experiment of large day-schools has been successfully tried, and the results are conclusive as to the superiority of the system from whatever point of view we regard it; their superior economy is obvious. Morally, we believe the gain to be also great. We want, in every considerable town in England, a high school for girls, which should offer the best possible education on moderate terms—one which should serve as a model to all those private establishments for which in future, as at present, there will no doubt be abundant room. To such a school as this it would be very easy to attach all manner of appliances and apparatus in the way of lectures and special classes, which might be attended from private families or smaller schools"

Since these words were penned, thirty schools for girls have been established by the Girls' Public Day-schools Company, originated by Mrs. Gray, who sagaciously hit upon this commercial means of extending this new system of education for girls. The system, however, is equally applicable to boys, and a Boys' Public Day-schools Company has also, but more recently, been established.

The resources of the former company have, as yet, been chiefly employed in the establishment of its schools, and it has been obliged to hire houses for school buildings. At Croydon, Blackheath, Gateshead, Oxford, and other places, new schools have been built, and I myself engaged in the design and erection of the South Hampstead High School for Girls, of which I was one of the original promoters, and in which I was desirous of giving an inexpensive illustration of the principles hereinafter advocated, adapted to a school for 300 pupils. (See Plate 54.)

The system of teaching adopted in these schools is very similar to that elaborated at those which may be regarded as the earliest of girls' day-schools, viz. the North London Collegiate and Camden School for Girls, founded by Miss Buss more than thirty years ago. The remarkable success of these upper and lower middle-class day-schools is proverbial. They now contain nearly 1000 pupils, and several hundreds more are patiently waiting their turn for admission as vacancies occur.

On the application of the Brewers' Company, the Charity Commissioners projected a scheme whereby certain valuable educational endowments, belonging to that company and the Clothworkers' Company, have been devoted to the development of these schools, thus enabling the trustees, to whom Miss Buss had handed them over, to erect, for her foundation, representative buildings of their class. As the architect to the trustees for carrying on the said day-schools, I shall take occasion to point out the peculiarities of their construction ; illustrations are given in Plates 59 and 60.

With these preliminary remarks, I now proceed to offer some practical suggestions, with the view of popularising a subject not, generally, too well understood. It may be convenient to consider the question under two heads :—

1. The general arrangement of the buildings as a whole.
2. The particular planning of the parts.

PART I.

As to general arrangement, let it be granted that the site is all that could be desired, with a hard gravel subsoil, slightly elevated, well-drained, surrounded by play-grounds, chiefly extended towards the sunny side, the aspect being such that a few northern-lighted rooms may be obtained for artistic purposes ; the main class-rooms shold be east by south, or west by north, that they may not be too cold in winter, nor too warm in summer, and may at all times be bright and cheery. The class-room windows should not be less than 50 feet from any opposite buildings, and their area of light not less than one-fourth of the floor space, and, if the windows are on one side wall, the opposite wall should not be more than 25 feet distant, so that the farthest desk may have sufficient light ; 15 square feet is the maximum area required for each pupil, and 14 feet a maximum height ; the minimum area should be 12 square feet, and 12 feet height. Inlets for fresh air should be opposite the foul-air extracts, arranged for use in the varying proportions required in summer and winter, and entirely under the control of the teacher ; some, at least, of the extract shafts should be heated at the base, and the fresh air admitted should be capable of being warmed on its passage into the room. However contracted the site, it is to be hoped that room will be found for a fives-court, and for the simpler kind of gymnastic exercises, both covered and uncovered.

Secondary school buildings naturally divide themselves into two distinct classes, viz. boarding-schools and day-schools.

Boarding-schools.—With reference to the first, it is not my intention to say very much, because it is not in this direction that the extension of educational buildings is likely to be very greatly increased ; nevertheless, it is very important that the improvements made in day-schools should be imported into boarding-schools, and that the accommodation required for residentiary purposes should not overbear or prejudicially influence the educational department and its appliances.

It has been one of the drawbacks to the proper development of voluntary schools, that the promoters were too often willing to sacrifice the school conveniences for the sake of

obtaining space for popular lectures and general assembly rooms, and the Education Department very properly set their faces against innovations of this sort wherever their influence extended. At the same time, the great cost of extensive dormitories and domestic offices in boarding-schools renders it essentially necessary to bear in mind the double purpose of such buildings, so that each may be economically arranged, and the provisions necessary for the one purpose may not lead either to curtailment or extension beyond the requirements of the other.

As an example of the kind of building which, in practice, has been found to answer the ends proposed, I may refer to Plate 55, which illustrates Milton-Mount College, Gravesend. The educational division of the building occupies the ground-floor of the main block, consisting of a southern front and eastern and western wings, over which are two stories of dormitories; the dining-hall—a single-story building, with an open-timbered roof—is situated in the centre, and is placed at right angles with the main building, and, being situated immediately opposite the entrance-hall, is easily accessible for public uses or school lectures and examinations, while at the other and northern end are the kitchen offices quite distinct from the rest of the building, yet closely associated therewith by the corridor running on the side of the hall. The pupils' staircases occupy the internal angles at the junction of the main building with the wings, while in the centre is a service staircase, at the southern end of the corridor, connecting the main building with the domestic offices. By this arrangement, the several parts of the building are in close connection and yet perfectly distinct:—The educational apartments, with the teachers' and pupils' dormitories above them; the kitchen offices, with the servants' dormitories over them; and the dining and lecture-hall between. The original plans have been somewhat varied in execution. The infirmary has been omitted, and the left wing has been extended northwards for a science laboratory and lecture-room with dormitories over. The laundry has been built on another site, and a gymnasium occupies the right quadrangle.

The late architect of the London School Board, Mr. E. R. Robson, F.S.A., in his admirable work on school architecture, has chosen this building as an example of a middle-class boarding-school, and has given four illustrations of it. I cannot do better than quote his succinct description. He says:—

"Milton-Mount College, Gravesend, intended for the daughters of Congregational ministers, and erected from the designs of Mr. Robins, forms a rare specimen of a carefully considered school-house for 150 girls, on the boarding principle. The sleeping apartments on the first floor are planned on the model of the ancient monastic dormitories, a central corridor down a large hall or room, leading, on right and left, to cells, chambers, or cubicles, formed by wooden panelled or match-boarded partitions, 6 ft. 6 in. high, arranged along both sides.

"The monks' dormitory at Durham, erected in the fifteenth century, and now used as a library, was identical with this in plan. The advantage of the arrangement is that each scholar has a room to herself, while ventilation is promoted by the upper part of the room being entirely unencumbered by divisions. The cubicles measure 9 ft. 6 in. by 5 ft. 8 in., and occasionally two are thrown together, by the omission of the partition, for occu-

pation by two sisters or friends. A drawing shows an interior view, supposing the partition removed for the purposes of a sketch.

"On the ground floor are the school-rooms, class-rooms, teachers' and visitors' rooms, library and music-rooms; the last are fitted with shelves and portfolio lockers. The little practising-rooms each contain a piano, and it is found that sound from room to room is sufficiently deadened by the plan for the purpose in view. In each of the school-rooms book-closets are formed against the wall dado, and surround the room. One school-room is fitted with a raised gallery and Dr. Liebreicht's desks; there are four class-rooms, each for twenty pupils; the bonnet and cloak-rooms are fitted with separate closets for every three girls; the dining-hall is capable of accommodating 150 girls and eight mistresses. The arrangements of the dormitories on the second floor are identical with those of the first floor."

Now there is nothing in the design of this building, which would not make it equally suitable for boys, excepting only the music-rooms, which might be converted into science class-rooms. The same may be said of another example of this description of building, viz. the Educational Home for the Daughters of Missionaries, Sevenoaks (Plate 56), the foundation-stone of which was laid by the Right Hon. the late W. E. Forster, M.P.

In this building I have carried out the same principle of planning, but so varied as to suit the special circumstances of the case. In this boarding-school, 100 children have to be accommodated and divided into senior and junior schools, the senior occupying the left wing and the junior the right. Cubicles are provided in the dormitories for the seniors, but not for the juniors, for which latter class nurses' rooms are required, and bath-rooms for all.

The dining-hall is in the same relative position as at Milton Mount College, with the kitchen offices and servants' dormitories in the rear; but in this case, and in consequence of the delicacy of children, born mostly in foreign countries, it was thought desirable to form the building into a quadrangular shape, with internal courts on either side of the dining-hall, so as to be less exposed to northern winds, and more compact and warm, the corridors themselves being heated. Both here and at Milton Mount ample space is given for cloak-rooms and conveniences, which, in each case, are projected from the main building, under lean-to roofs, towards the internal courts. An unwise economy usually contracts the space allotted to cloak-rooms, lavatories, &c., so as to make them greater nuisances than conveniences.

The Congregational School at Caterham (Plate 57) is an example of a residentiary Institution for 150 boys, and differs from the foregoing inasmuch as the dormitories have separate lavatories and no cubicles: the school-room occupies the ground floor of the right rear wing and the dining-hall the left, next the kitchen offices, while the space between is occupied by the gymnasium, with cloak-rooms next the corridor and the conveniences in the rear.—Some old buildings are incorporated with the kitchen offices, while the master's residence is but an old house remodelled.

Day-schools.—I now come to the general arrangement of middle-class day-schools. In considering these, it will be useful to observe the four typical examples of elementary schools; in the first place see the illustration given in Plate 58 of Christ Church Schools,

Battersea, which were erected by me many years ago for 600 children—200 boys, 200 girls, and 200 infants; they were designed on the old system then required by the Educational Department, and consisted of one long room and one class-room to each division, the classes in the long room being divided by curtains drawn out at right angles from the walls. This school was erected at the then stipulated cost of 4*l.* per head, exclusive of the two teachers' houses.

2. On the establishment of the London School Board, various architects were engaged on the first schools projected, one of which fell to my share, viz. the Wapping School. The improvements very early made by the School Board, are exhibited in this design for a school for girls and infants only, as shown in the more compact planning, the increase in class-room accommodation, and the introduction of dual desks, &c. (see Plate 58).

3. This tendency towards the increase of class-room accommodation is in accordance with German examples, and one of the most approved by the late Mr. Watson and Sir Charles Reed is Haverstock-hill School, designed by Mr. Robson (see Plate 58). In this case there are four class-rooms to each large school-room, all of which are on the ground floor, each of the large school-rooms giving space for as many desks as the four class-rooms belonging to it together contain; but with this striking peculiarity, that the central space, around which these school and class-rooms are arranged, is covered, and forms a hall of assembly, wherein the whole school meets daily, and in which examinations can be held, and through which access is gained to all the classes, the glazed doors to each of these being commanded from the daïs in the hall. This hall was originally designed as a girls' covered play-ground, and is so described in Mr. Robson's book, but experience has proved its great convenience in administration, and it is no longer used only as a play-room, but contributes not a little to the educational success of the institution. The "hall-passage system" had thus an accidental birth.

4. In Johnson-street School, Stepney, designed by Prof. T. Roger Smith, the large school-rooms were thrown aside altogether, and the one great hall alone retained, with separate class-rooms surrounding it on three sides, and all in direct communication with it (see Plate 58). This school was professedly based on the Prussian system, but is a great improvement upon it, and is the best example of what Dr. Abbott has happily termed the "hall-passage system," adapted to schools of more than one storey in height. I look upon this as the culminating point to which primary school buildings have grown, and I take this as the starting-point from which progress is to be made in the future development of secondary schools. That I am justified in this opinion, the afterwork of these gentlemen is confirmatory, inasmuch as Prof. Smith in his unaccepted design for the Grocers' middle class school for boys, and Mr. Robson in his executed design for the Blackheath School for girls, have both adopted the "hall-passage system" as the basis of their planning.

Mr. Henry Clutton also chose the same principle in his design for St. Francis Xavier's College at Liverpool, erected, in 1875, as a middle-class day-school for 500 boys.

The advantage of so planning a school-building that the head-master may, with the least loss of time and trouble, have the whole school under his supervision and control must be manifest to every one who thinks of the difficulty of personally controlling a

school of 500 or 1000 pupils and their various masters. A hall into which every class-room door shall open, where the pupils may congregate for prayers, for lectures, for examination, for separate instruction in such groups as may be required by special circumstances, where they may meet and retire in an orderly manner to their several classes or to their homes, under the eye of the presiding genius of the school, is obviously an addition of no small importance to the welfare and discipline of the school.

The moment that you introduce the corridor you destroy the possibility of exercising the same kind of influence ; the hall, if you have one, becomes a costly appendage, of a stately character, but of no daily practical use, being reserved only for special occasions. The teaching being done in the class-rooms, it has not the excuse for its existence which the old foundation-schools had, for in them no class-rooms were provided.

For these reasons I prefer Prof. Smith's design for the Grocers' School to that which has been chosen and erected, where the hall is carefully cut off from the class-rooms by a corridor, which effectually isolates it, and gives to the head-master no personal control whatever of the movements of the school, as a whole, from such a vantage-ground, and thus the hall is rendered an expensive and comparatively useless luxury.

In designing the buildings required for the North London Collegiate School, at Sandall-road, Camden Town, and the Camden School for girls, at Prince of Wales-road, Kentish Town, I laboured under the disadvantage of having to incorporate therewith existing buildings in each case, and in the former to complete the new portion before I touched the old, so that the pupils might be transferred from the one to the other ; but, feeling very strongly the representative character of these schools, I endeavoured to bring them into subjection to the latest, and, as I think, the best improvements in school planning.

Camden School.—The illustrations on Plate 59 show the general arrangements, concerning which I may remark that the Camden School was first built and finished. The freehold of the Governesses' Institution, founded by Mr. Laing, was purchased for 5500*l.*, and, at a cost of some 7500*l.*, was adapted to the uses of the school. In this case, for economical reasons no hall was desired, it being determined that the Clothworkers'-hall at the Collegiate School should be jointly used by the two schools on prize-days, &c. Subsequently, however, a hall was built in the rear, which does not appear on the plan.

The education given at this school is at a much lower rate than at Sandall Road, and the classes number fifty pupils in each ; on the ground and first floors there are nine such class-rooms, a gymnasium, a drawing-school, a lecture-room, library and committee room, teachers' rooms, office, and caretaker's apartments ; in the basement are the extensive cloak-rooms, drying closets, dining-room, kitchen, and domestic offices.

The girls enter by the basement steps on each side, proceed to the cloak-rooms, thence pass up to their several class-rooms, where each has a separate desk to herself ; the use of the gymnasium, drawing-school, lecture-room, and playground being timed with great precision. Both hot-water and open fire-stoves are used for heating and for drying clothes, and every class-room has arrangements for admitting fresh, and extracting foul air, independently of the windows. Owing to the administrative abilities of the

head-mistress, no less than the completeness of the arrangements, this school goes like clockwork.

North London Collegiate School.—The old portion of the North London Collegiate School for Girls was originally an emporium, or general store, and was adapted by me for school uses. It has undergone considerable alteration and addition, an extra floor and a new façade having been constructed. The new buildings occupying the remaining portion of the site were opened by the Prince and Princess of Wales in July, 1880.

It will be seen by the illustrations on Plate 60 that the accommodation is ample, it comprises the following :—The great hall, presented by the Clothworkers' Company, and called by their name, 70 ft. by 39 ft., and 32 ft. high, with a wide gallery at one end and a shallow one on the side at the level of the first floor, the raised daïs and organ recess being at the opposite end on the ground floor. Three stories of class-rooms are arranged on one side of the hall. The five class-rooms on the ground floor, and those over them on the first floor, are in direct communication with the hall by the ground floor of hall and the side gallery. Two of the class-rooms may be thrown into one, by opening the sliding doors provided between them. There are three class-rooms on the second floor and a large drawing-school lit in a similar manner to the Gloucester Art School.

Under the great hall is the dining-hall, and the kitchen, scullery, and housekeeper's room ; under the class-rooms are the cloak-rooms and conveniences, the store-room, the teachers' room, the strong room, the head-mistress's retiring-room, and the drying-room.

The basement and staircases are heated with fresh warm air by hot-water pipes in channels to which fresh air is admitted in large quantities. The class-rooms have Boyd's School Board ventilating grates ; fresh-air admission shafts and foul-air extraction shafts are everywhere, so that the necessity for opening windows is not felt, though cross ventilation by windows is easily attainable, not only by the fanlights over the doors to the hall, but by windows in the same intermediate wall. The triangular space over the boarded ceiling of the great hall forms a warm-air extraction shaft, hot-water pipes being placed at the foot of a vertical flue at one end thereof.

There are two staircases to this new building, one at each end of the corridor. This portion of the school was in occupation some eight months before the other was altered, and the advantages of the "hall-passage system" were fully proved ; otherwise, in spite of the known administrative ability of the head-mistress, it would have been impossible to accommodate the whole school of upwards of 400 pupils without the use of the old part of the building.

It is an interesting sight to see the pupils come in through the basement entrance to the cloak-rooms, where they enter at one door and retire at another, changing their shoes as well as leaving their hats and cloaks, and passing up the staircases to the great hall, where they file in to their accustomed seats and await the organ peal giving forth the morning hymn, followed by the prayers read by the head-mistress, at whose command each teacher leads her class to its class-room : after which the doors are shut, and work begins within and also without, in the great hall and gallery, which supplement the class-rooms where required.

The Old Building.—On either side of the main entrance to the old building are small triangular offices, at which enquiries may be made without further entering the building, at small windows provided; beyond these, on one side, are the head-mistress's rooms, and on the other side, general office and waiting-room; adjoining this is the board-room, which is also the library and museum. Over the board-room, on the first floor, is the science lecture-room, with a chemical laboratory adjoining; the other two rooms are respectively a class-room and the teachers' retiring-room and library. The old staircase is retained to reach this floor, but the new staircase gives access to the second floor, in which are two large and five smaller class-rooms for music lessons and practice. The caretaker's rooms are reached by a special staircase, and extend from the front under the turret to the back; a box-room is situated in the turret itself, and a lumber-room in the general roof. Behind the organ are passages on each floor, and a lift from the sub-basement and coal-cellar to the lift and cistern-room on the topmost floor. Two drinking-fountains are provided for each floor, supplied with filtered water, and lavatories and W.C.'s in addition to those entered from the cloak-rooms. The basement is occupied by a cloak-room 30 feet square, a cooking-school and scullery, &c.

It must be confessed that, upon this very awkwardly shaped site, very little else could have been done had the entire buildings been altogether rebuilt. The playground is much too small, even with its enlargement, and is partly occupied by the gymnasium, 100 feet long by 25 feet wide, which is fitted with Stempel's apparatus; a fives-court has been formed out of an old stab e in the rear.

Such is a general description of these schools, to which have recently been added a museum and library, with a covered playground below, and a chemical laboratory above, for details of which last, see Plate 52.

My design for the City of London School on the Thames Embankment was a further development of the same principle of planning which I have been advocating, but it was as fatal to my success as to Prof. Smith's in the Grocers' School competition. The public had not yet been educated up to the "hall-passage system," and the *selected* plan in this competition repeats what I considered a defect in the plan selected in the latter case, viz., the great hall is made a solitary apartment, carefully cut off from the uses of the school by the corridors surrounding it. In other respects the plan is suited to the site, but the school would be as complete without the hall as with it.

In the design submitted by me, the hall was made the centre of civilization to the school; into it every door to every room in the building opened, and from the raised daïs was commanded every part of the building and all the people in it. This hall was like the nave of a church, with a range of clear-story windows above the roofs of the class-rooms surrounding it. It took away the necessity for close, stuffy, dark and dreary passages, and gave a cheerful hall as a promoter of light and ventilation. It had a gallery round it, at the level of the first and topmost floor. The class-rooms on three sides opened into it, and the great lecture-room for 400 students was at one end, in easy communication with the chemical laboratories and class-rooms.

Under the lecture-room on the ground floor was the dining-room, capable of being divided into four class-rooms, and supplied by a lift from the kitchen on the second floor,

which was part of the caretaker's apartments. Benches were provided for the whole of the school on the ground floor, with aisles 10 feet wide running round and forming open passages of communication, never needing to be screened by curtains except on examination days, as experience had proved at Sandall-road School. The head-master's and secretary's room, the clerk's offices, and the board-room, with the separate waiting-rooms, were ranged on either side of the chief entrance from the Embankment. The basement was almost entirely devoted to covered playgrounds and cellarage, the fives-courts and conveniences being planned carefully with covered ways to the latter from the staircases. The head-master's private room overlooked the south-western corner, and the teachers' private common-room overlooked the playground at the north-west corner, so that out of school the masters were in the best position for observing the pastimes.

Prof. T. R. Smith's design for the Grocers' School was also most compact. The class-rooms were arranged on three sides of the hall, with which they were in direct communication, similar to the admirable Board school erected by him at Stepney.

As to Mr. Clutton's design for St. Xavier's College, I was not aware of its existence till, in searching for corroborative examples of the principles I am advocating, I found an illustration of it in the *Building News*. I wrote to the master to learn what his opinion was of the practical advantages to be gained from this arrangement, and the Rev. Father Harris replied as follows :—

"The opening of the class-rooms directly into the great hall has very great advantages. 1st, as regards general supervision ; 2nd, as regards saving of time ; 3rd, as regards all general discipline. It is, however, difficult to use the hall for any general purpose during school hours ; but, as far as the good of the boys, which is the principal matter to be studied in a college, is concerned, the system answers admirably."

I have also received the following note from Miss Buss, whose testimony is of great value :—

"During the time that we have had the use of the hall, we have found it exceedingly pleasant. The opening of the school-rooms directly out of the hall is certainly a great advantage. The supervision is much more easy, as is also the control of pupils while assembling and dismissing. The light and ventilation are excellent, far better and more complete than they would have been if you had given us a passage."

PART II.

I now proceed to consider the second formal division of my subject, viz. the particular planning of the parts ; but I fear the space at my disposal will necessitate a very limited discussion of the details.

The Lavatory and Cloak-rooms.—Every school is, or ought to be, entered next the hat and cloak-rooms, and the most convenient mode of retirement should also be by the same route, supposing always that the cloak-room does not form a separate adjunct to each class-room, as in the case of my design for the City of London School, wherein I endeavoured to realise the expressed wishes of the head-master, and arranged for the boys' entry into

the cloak-room on one side of each class-room and out at the other, the custom at the dismission being for the master to order the boys to file off from their class seats into the cloak-room, and enter again by another door to their seats, with the hats and coats with them; when all are ready the order is given to leave; in this way the loss of clothes is prevented. But the better plan is to have separate cloak-rooms, which may be heated and ventilated quite independently of the class-rooms, and the coats may be dried as they hang over the hot-water pipes, or, if very wet, can be taken to the drying-room. One of the most complete cloak-rooms, as well as the most extensive, in a boys' school of this kind, is that of Cowper-street School, Finsbury; and I am sorry to say, about the worst, are those provided in Board schools, where, if anywhere, it surely is most necessary to avoid the transmission of disease and other evils, by providing cloak-rooms of sufficient size, and not, as is most common, having two or more rows of pegs over each other, so that the garments hang one upon another; but the outcry against expenditure in Board schools will, doubtless, make it difficult to improve in this respect. In secondary schools, however, this ought not so to be, and yet it is the commonest sin in the most elaborate and expensive buildings in other respects, and not less in girls' than in boys' schools.

The provision made in the North London and Camden Schools is as economical as it is efficient, and the plan is this:—The cloak-rooms are situated in the basement, and consist of a series of rooms the same size as the class-rooms above them, surrounded on all sides with a single row of pegs, not less than 9 inches apart, a shoe-rack, and umbrella hook, with continuous metal water-channels, made moveable in short lengths. A screen down the centre gives space for a similar arrangement on either side of it; hot-water pipes pass under each screen, above the floor; between the rows, forms are placed for the girls to take off their walking-shoes; every peg is numbered, and every pupil has her number.

The lavatories are situated in the cloak-rooms, and the external conveniences are entered from the cloak-room; so that every arrangement is open to inspection, and under the control of the teachers on duty in each room. Some teachers prefer to keep the lavatories and conveniences separate from the cloak-rooms, so that the cloak-rooms may be locked up during school-hours. In boarding-schools it is usual to provide closets and doors with looking-glasses in the upper panels, &c.; but in all cases plenty of room is essential to the discipline and *morale* of the school.

The Class-rooms.—The arrangement of the class-rooms is one of the most important considerations. The number of scholars varies with the system of classification adopted. The Public Day-schools Company prefer from 20 to 25 in a class; the North London Collegiate School, for the higher education, apportions 30 to a class; the Camden School has classes of 50; a common number is 40, which is that adopted at the City of London School, but 60 is not an unusual number in great schools.

Continuous forms and desks, four, five, and six rows deep, are usual, but I prefer the dual desk to the continuous, and think the best arrangement is that adopted at the North London and Camden Schools, where each student has a single Swedish desk, set 15 or 16 inches apart so as to allow of a passage between each from front to back; the rows will need no space between them from side to side, but a 2-feet passage or more is desirable at

the sides next the walls, though not essential, the resulting area being from 12 to 15 feet each scholar. In all cases the light should fall on the left side of the desks; and, if the rooms are not heated by warm-water pipes, the fires should be opposite the desks; and not in the centre of the wall, but between the teacher's desk and the entrance door, so that the teacher's raised desk may stand in the centre, and the draught, if any, from the door may only feed the fire, without annoying the teacher, or the students.

On the opposite side to the fire, and behind the students' desks, vitiated air extract shafts should be built in the walls, with a large grating fitted with a gas-jet inside, and the means of closing, if desired, one at each side and close to the ceiling. The stoves should be on the principle of Boyd's School Board stoves, with fresh air passing through them into the room. Further fresh air may be introduced on what is known as Tobin's system, by shafts in the room or flues in the wall, under window-sills, opening through hit-and-miss ventilating gratings fixed in the window-boards. The latter plan is adopted at Sandall-road, but has the disadvantage of admitting the air too low, and the descending cooler air, next the cold window-panes, checks the upward current of the inlets. The wall opposite the windows, in which is the door, should be supplied with a large fanlight over the door, and corresponding dwarf window openings in the upper part of the wall, so that cross ventilation may be obtained at pleasure, and particularly in the intervals of teaching. The rooms should be 13 or 14 feet high, as wisely required in all Board schools. Class-rooms so designed and arranged on one, two, or three sides of the great hall, form the largest part of the school-buildings, and are adapted to every purpose required.

Drawing Class-rooms.—In addition to a northern light, a high light is desirable; and not only so, but a skylight also; and this is best attained by a curved roof, similar to that adopted at the Gloucester Fine Art School, and to that which I have built for the North London School, where I have formed the roof with iron ribs and sash-bars on one side, and glazed it like a conservatory, lining with boarding so much of the interior as the circumstances of the case required as proved by actual experiment.

Science Class-rooms.—I have already referred to the great changes which have recently taken place in school-buildings, the single lofty hall which constituted the whole school fifty years ago being now superseded by a variety of separate class-rooms and other conveniences. But this change in the architecture has been accompanied by a yet more marked revolution in the mode of teaching, and in the matter taught. The education of the memory, which was all that was provided for our fathers, is in these latter days giving place to the education of the mind. To develop the reasoning faculty is now considered a nobler task than to manufacture walking encyclopædias, and, since it is now generally accepted that one of the most powerful instruments for the cultivation of the reason is the study of science, it is evident that chemical and physical laboratories—and, possibly, even mechanical laboratories—will henceforth be considered essential parts of a first-rate school. These secondary laboratories will also be associated with one or more lecture-rooms to accommodate from 100 to 200 students; above that number, it is better to have two lecture-rooms.

The particular form of chemical operating-stalls, the service of gas and water, the sand-

baths, and the fume-closets, are illustrated in the drawings already given, and may be further studied by reference to the illustrations of the admirable laboratories at Owen's College, Manchester; but, as I am not aware that similar publicity has been given to physical laboratory fittings, I have given a few illustrations of the very clever arrangements designed by Professor Ayrton for the college at Yedo in Japan, which his kindness has put at my disposal. (See Plate 45.)

I may, however, remark that the chemical laboratory operating-stall should be from 3 to 4 feet wide and 2 feet 3 inches deep, with two tiers of bottle-shelves at the back, two gas jets with "Bunsen" burners, a basin of lead or of stoneware; the latter is less affected by acids, but the former is easily repaired or renewed, and fewer breakages occur in its use. If the laboratory is small, one sink in the corner, or next wall, will be all-sufficient, as at Sandall-road. Different-sized drawers are required under the oak table-top, and the remaining space may be provided with shelves, with doors to enclose the same, set back to allow space for knees when sitting at the stall.

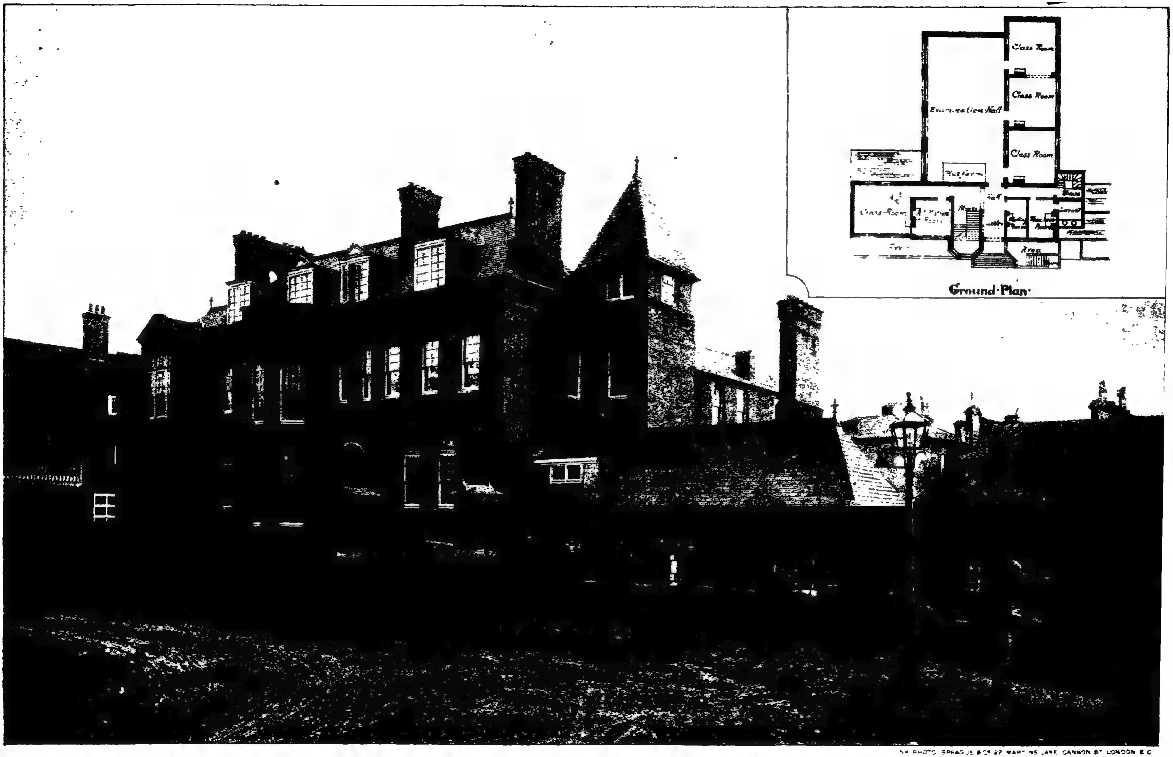
The fume-closets should be formed with lead-lined sink and closet under, enclosed with panelling (if not recessed in the wall), with rising sashes in front; in the bottom rail of the lower sash hit-and-miss ventilators should be fixed, to admit air from the room to the chamber, at the upper part of which is a ring of gas jets at the foot of an extract flue. A better plan is adopted at Owen's College. All the fume and exhaust-closets are connected by channels with a lofty chimney, at the base of which a furnace is constantly burning, and the draught created by this sucks up the air from the fume-closets, and carries it far above the buildings. A directors' room, best apparatus-room, balance-room, and special operation-rooms are desirable additions

The Science and Art Department of the Committee of Council on Education at South Kensington, continue to supply their science form, No. 1013, descriptive of simple fittings for laboratories, and with it a series of drawings; they are the result of much deliberation, and practical experience has proved their value. The Royal Institute at Hull is furnished with these fittings, which are suitable for advanced classes. The Gloucester and the Watford Art and Science Schools are illustrated in Colonel Donelly's reports, and may be consulted there. These buildings aptly illustrate what is required to complete secondary school buildings. Their existence as separate institutions proves that the want has been felt and provided for in this way; in future buildings the want should be anticipated.

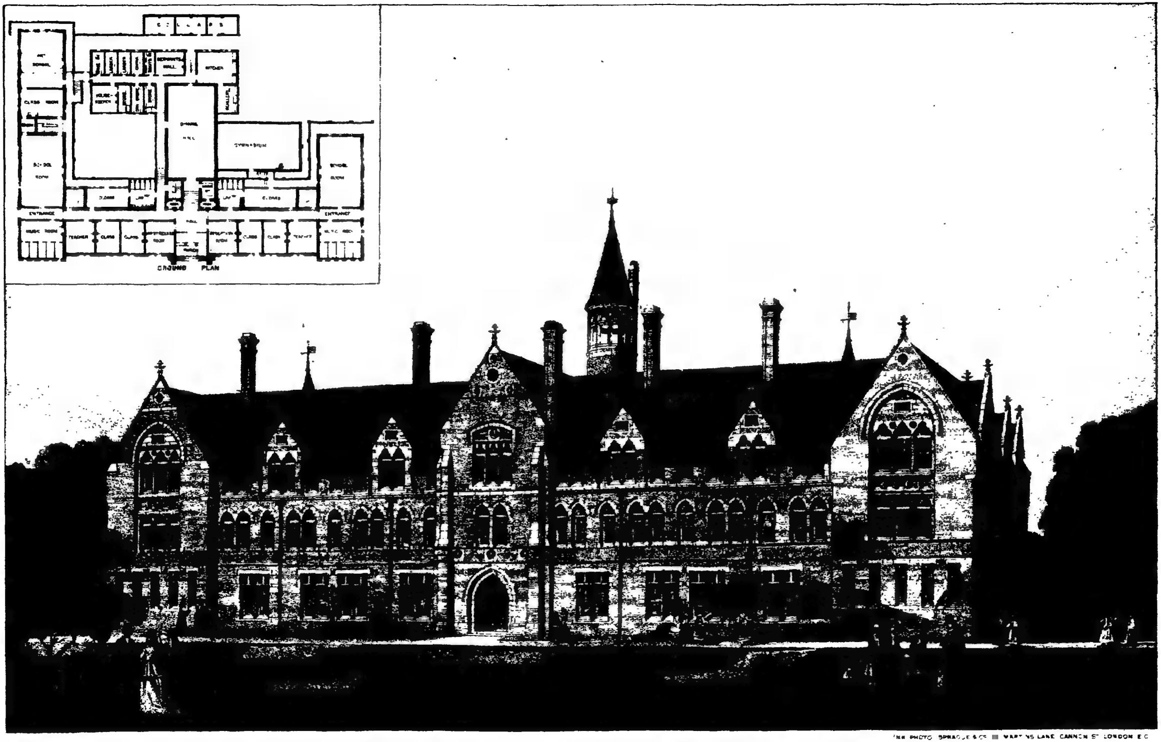
The need of technical knowledge, based on scientific principles, is daily becoming more apparent, and our secondary school teachers will find it to their own interest, no less than that of the middle classes generally, to give increasing attention to it.

In conclusion, let me express a hope that buildings for secondary educational purposes will no longer be considered unimportant accessories to the fuller development of the teaching power of the master, and the acquiring capabilities of the students, and, whether the authority of Government is applied to the removal of the present inconsistencies or not, that the English people will in this, as in most other things upon which it exercises independent thought, achieve its own emancipation from the thraldom of habitual apathy and contented submission to things as it commonly finds them.

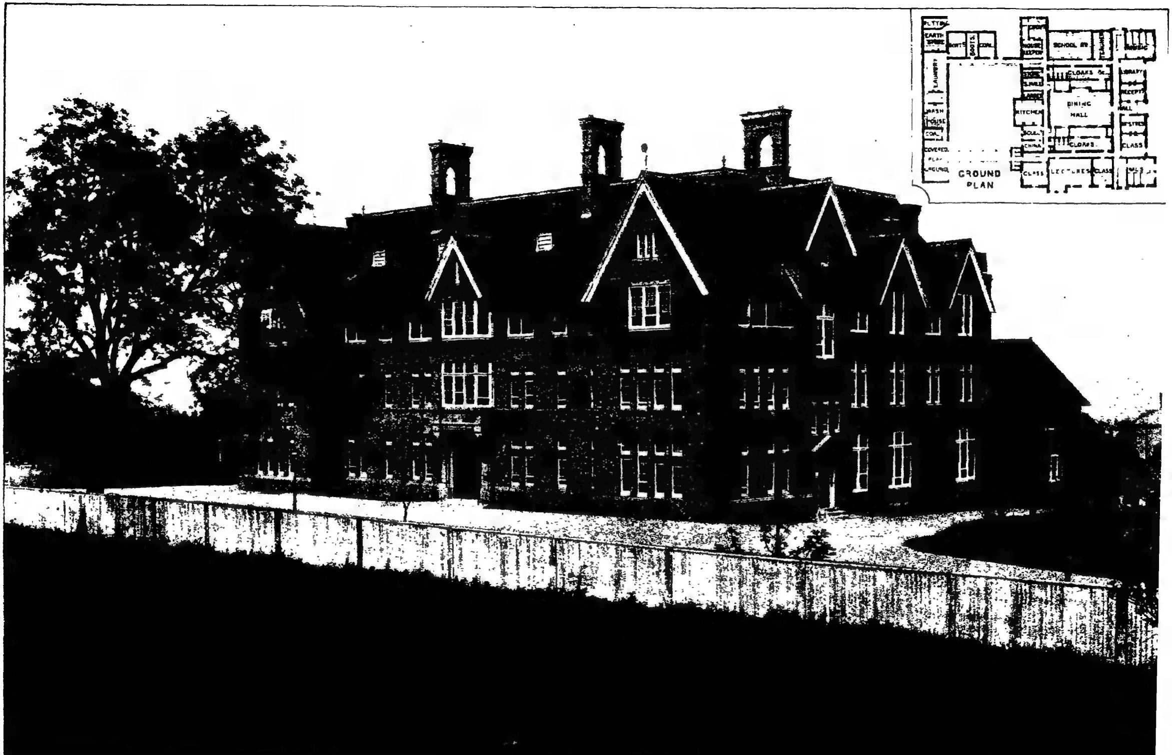
Professor Williamson has well remarked "that the technical education to be given to the young people of the country, should be of such a kind as would prepare them for a useful career in life. It would be tedious to give any outline of the various principles which had been proposed to guide a system of technical education, but he had recently formed, in his own mind, a notion which he should be glad to submit partly for the reason that it differed essentially from one which he had brought forward on other occasions, and which he was still inclined to think correct as far as it went. The technical education, which was being taken up by the great and powerful corporations in the City of London, ought to do something really great. The rich could take care of themselves; they could easily get, more or less efficiently, the various good things of life, but the poorer classes could not, and it was these whom it was most important to reach. What had been done up to the present time fell short of what was required. Mechanics' institutes, as the name denoted, were intended to give education to the sons of mechanics, but they had not thoroughly succeeded. They had been useful, and successful to a great extent, but they were, in the main, attended by the middle classes. It was a difficult problem to solve what kind of instruction was suited to children of from 14 to 18; and in order to render his meaning more clear, he might contrast it with the opposite view which he had previously referred to. The general notion which was entertained of the most complete system of technical education, was that it should consist of two phases; first, a most thorough scientific teaching; and secondly, actual experience in the workshop. Of course, for the children of the poorer classes, it was utterly out of the question that they could have anything approaching a thoroughly scientific training, and the difficulty was to see what could be done for them in that direction. The idea which had latterly been assuming shape in his mind was this, that it would be natural, and practical, to begin at the other end; not to begin, as was at present done in the higher schools, with science itself, but to begin with the workshops and factories. In the case of lads in factories performing operations which they did not understand, but which they had learned to do empirically, they might be taught by competent teachers, in laboratories fitted up at the works, the particular conditions upon which the success of their different operations depended; as, for instance, in the case of dyeing, they might be taught the common impurities, and how to detect and remove them; they should be taught just as much, and no more, of the scientific principles as was needed for the clear and accurate performance of the operation in which they were engaged. In some cases, this was already being done, as, for instance, in the art of brewing, where Dr. Graham had already instructed many pupils how to detect and remedy defects which had existed for years. The difficulty of doing this was, no doubt, enormous, owing to the fact of their not having the necessary teachers; and these teachers would have to be grown, so to speak, before the difficulty was overcome. For secondary training, he believed that laboratories were destined to occupy a more prominent place; in fact, that technical education for the masses would consist in teaching them, not merely to perform the operations of their respective trades, but to understand the nature of the conditions required for the success of those operations. In the interest of science, very great results might be anticipated from such work as he had described. He could hardly doubt that, if perfectly accurate, though not high, instruction



SOUTH HAMPSTEAD HIGH SCHOOL FOR GIRLS.
E. C. Robins F. S. A. Archt



MILTON MOUNT COLLEGE. GRAVESEND.



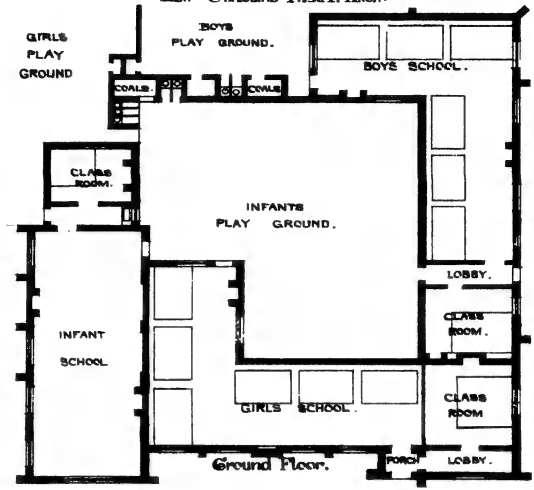
INK PHOTO. SPRAGUE & Co. MARTIN'S LANE, CANNON ST. LONDON, E.

WALTHAMSTOWE HALL, SEVENOAKS.

THE CONGREGATIONAL MINISTERS' BOYS SCHOOL.

Christ Church School · Battersea.

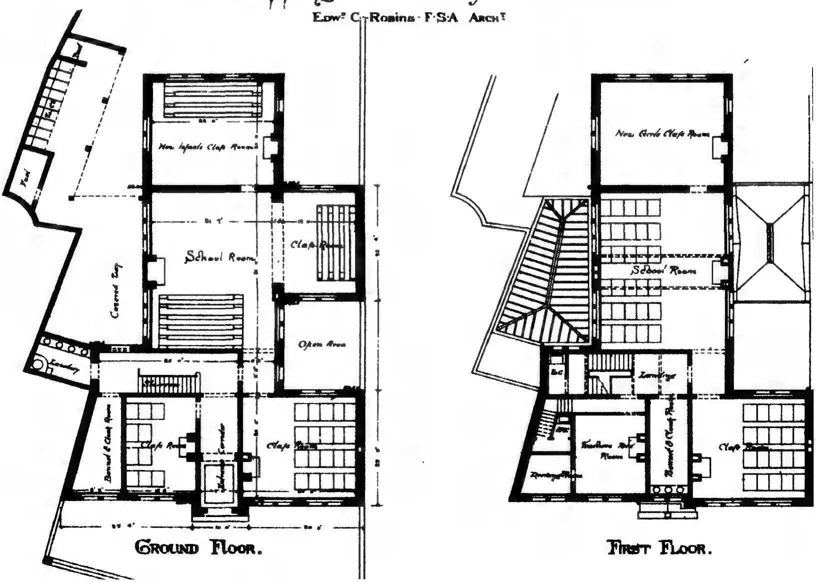
Edwᴰ C. Robins F.S.A. Archᵀ



Ground Floor.

Wapping · Elementary · School ·

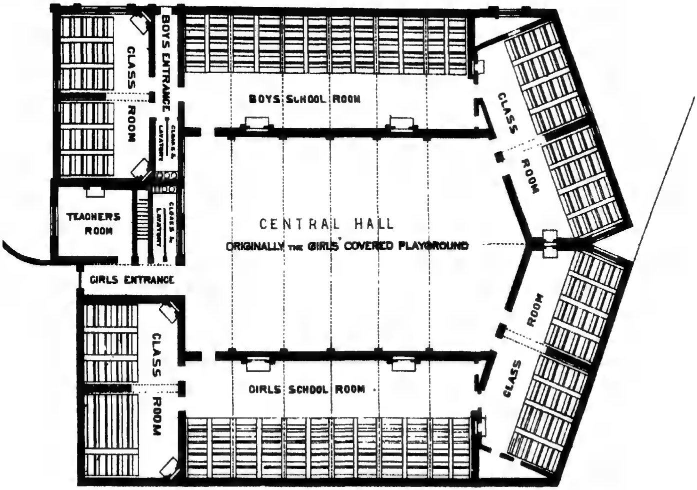
Edwᴰ C. Robins · F·S·A Archᵀ



Ground Floor. First Floor.

Haverstock · Hill · School ·

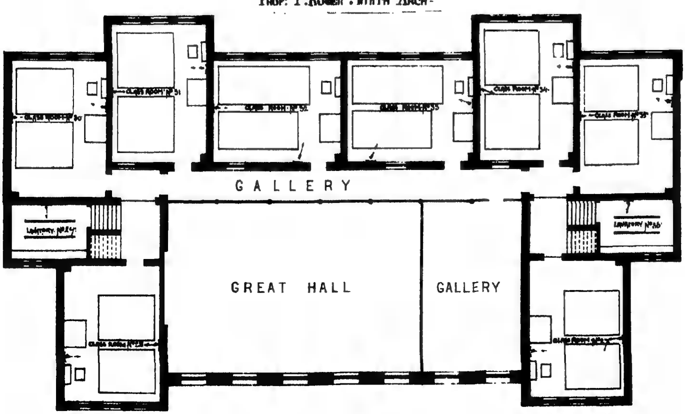
E. R. Robson F.S.A. Arch^t

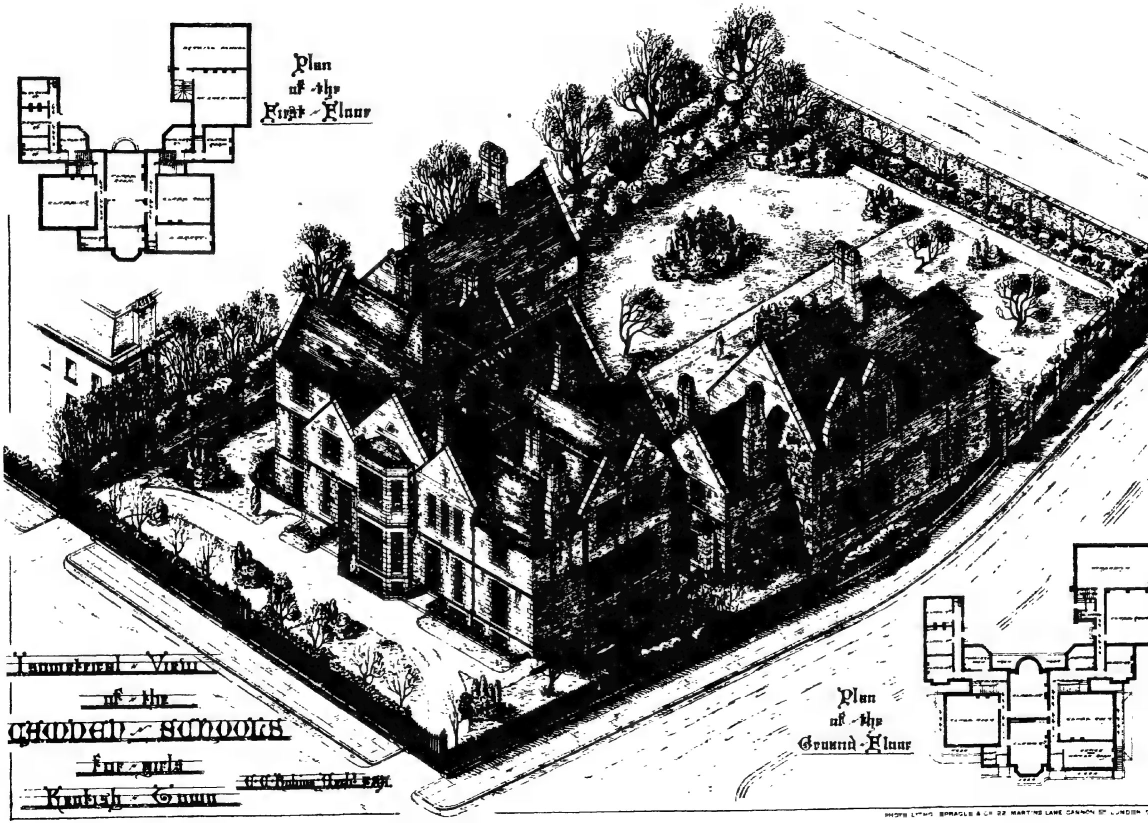


GROUND · FLOOR ·

Johnson · Street · School : Stepney ·

Prof: T. Roger Smith Arch^t




Plan of the First Floor
Plan of the Ground Floor
Isometrical View of the Camden Schools for Girls Kentish Town
PHOTO LITHO. SPRAGUE & CO 22 MARTINS LANE CANNON ST LONDON E.C.

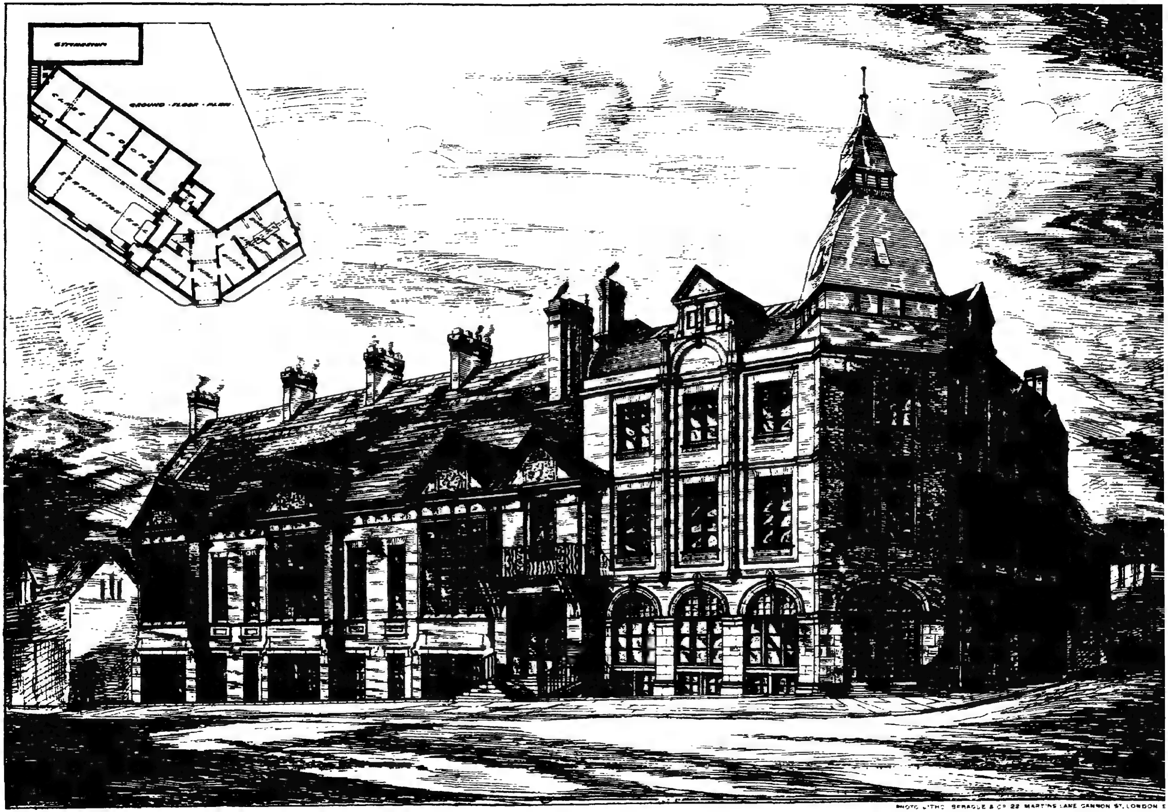


PHOTO LITHO. SPRAGUE & Co. 22 MARTINS LANE CANNON ST. LONDON E.

THE NORTH LONDON COLLEGIATE DAY SCHOOL FOR GIRLS.

were given to large numbers of the youth of the working classes, many would be stimulated, from the delight of doing things in an accurate and intelligent way in which they had never done them before, to educate themselves further by any available means. He trusted that he had rendered his general idea intelligible. The great thing to aim at was to give the lower classes an accurate knowledge of rudimentary scientific facts, so that they might, after a short time, be able to earn higher wages than they did now, and so encourage others to follow their example."

CHAPTER X.

SANITARY SCIENCE IN ITS RELATION TO CIVIL ARCHITECTURE.[1]

No subject of study can be more useful and honourable than that of the principles which should govern the direct application of Sanitary Science to the development of our national architecture—no duty greater than the recognition of our responsibilities in this matter, and of fitting ourselves for it. The growth of contaminating influences injuriously affecting the healthfulness of the elements, the earth upon which we live, the air we breathe, and the water whereof we drink, is commonly the result of culpable ignorance of the simplest sanitary laws, and of the appropriate mechanical appliances necessary to give effect to them. This is generally acknowledged in the abstract, and there are few subjects upon which philanthropists are more ready to expatiate, or more reckless in the adoption of any suggestion which sounds sufficiently iconoclastic or revolutionary.

Those of us who, for the last five and thirty years, have practically shown our interest in this subject, of course cannot be otherwise than pleased to observe the improvement in public opinion, and the quickening of the professional conscience, thereupon. Such men as Mr. Chadwick, Dr. Richardson, Captain Galton, and many more, are working with us and not against us, and we shall not grudge to them the credit they undoubtedly merit, because the public are less familiar with the names of those architects, who, led by Mr. George Godwin, formerly the accomplished editor of the *Builder*, have fought for long years, through good report and evil report, against the prevailing ignorance and apathy.

The useful and eloquent articles in that newspaper, during the visitation of cholera in the year 1852, first led me to take a personal interest in this question, and ultimately to allow myself to be associated, as Honorary Architect and Secretary, with the Local Board of Health for the parochial district of Regent Square Church, St. Pancras, under the presidency of the Incumbent. In this capacity an opportunity was afforded me of establishing a precedent for local sanitary exertion, and preventing the spread of disease in that particular locality, which comprised one-seventeenth part of the whole parish of St. Pancras. The result of this experimental enquiry was published in the year 1854, in a

[1] This chapter was the subject of a paper read at the Royal Institute of British Architects, in November, 1880.

pamphlet entitled "A Practical View of the Sanitary Question." A thousand copies were printed and circulated throughout the country, and the receipt of one was acknowledged by the late Mr. Tom Taylor, then Secretary of the General Board of Health, as follows :—

"I beg to acknowledge with thanks the receipt of the Report of the Local Board of Health for the Parochial District of Regent Square Church, St. Pancras, and to express the great satisfaction which the contents of that Report have caused to the President of the Board (Sir B. Hall)—a satisfaction expressed to me in the strongest terms- and to myself, as a record of a most successful effort of local activity, which cannot be too widely disseminated. I should be much obliged if I could be furnished with twelve copies of the Report for the use of this office."

The Commissioners of Sewers asked for sixteen copies of that document, which set forth that no less than 1017 separate sources of infection had been abolished by the Board's action.[2] Two Metropolitan graveyards were closed by special appeal to Lord Palmerston, the then Home Secretary, and assistance was rendered in revising the Bill to amend the Nuisances Removals Act of 1848-9, at the solicitation of Sir Benjamin Hall, its proposer, a Bill which subsequently became law. That was the period at which the Main Drainage of the Metropolis was under discussion, resulting in the establishment of the Metropolitan Board of Works to carry it out.

As a member of the then Metropolitan Sanitary Association, I was most earnest about the establishment of a corps of sanitary surveyors to be appointed by the Act, as well as medical inspectors, and I was one of a deputation to the Home Secretary on the subject. It was with great pleasure, therefore, that I read the following paragraph in the concluding chapter of Captain Galton's "Observations on the Construction of Healthy Dwellings :"—

"It is the function of the sanitary engineer, or local surveyor, to adopt measures to prevent or to remove those sources of danger to health which the medical officer is called upon to detect. The community does not permit any man to practise medicine without having satisfied a careful and responsible board of examiners that he has educated himself for his position, and education in the principles of Sanitary Science is just as necessary to ensure the efficient fulfilment of the duties of a sanitary engineer or local surveyor, as is the study of medicine to the medical man. . . . . When the public realise that the progress of the nation in healthiness is to be attained by a careful attention to these details, they will insist that the local surveyor or sanitary engineer shall have a complete education in the science of the healthy construction of buildings, and in the arrangements for health to be adopted in towns and villages ; that is to say, in the conditions necessary for the *prevention* of disease, just as at the present time they require education in those who minister to the *cure* of disease."

Mr. Chadwick is of opinion that the subject of house drainage should be cultivated as a speciality, and he attributes to our professional negligence many existing evils. Sanitary science is indeed not so old but that architects of the last generation may be found often as ignorant of sanitary law as were their medical contemporaries. I readily admit that the

[2] "The Local Board of Health owed its origin to the exertions of the Incumbent of Regent Square Church, the Rev. Geo Albert Rogers, who invited a few benevolent individuals, being members of his congregation, to unite themselves with him for the purpose of remedying the sanitary evils existing in the district. The following are the names of those gentlemen who were invited by the Incumbent to attend the first meeting held at his house on the 18th of October, 1853 :—Rev. J. Hilmer, J. E. Clowes, Esq., Dr. Sawyer, J. Nokes, Esq., Henry Raven, Esq., J. A. Russell, Esq., Chas. Wyman, Esq., Mr. Brown, Mr. Genever, Mr. Thomas, and Mr. Westbrook. Several other gentlemen of the district were afterwards associated

education of an architect is incomplete when he allows his mind to be so absorbed by the artistic side of his profession as to look with contempt on the practical. It is true that the architect is *par excellence* an artist, and his works should take their stand among the fine art memorials of his age; but the arts of construction are important means to that end, and are to him what anatomy is to the figure-painter. It is equally true that the engineer is *par excellence* a constructor, and not necessarily a man of taste at all. The grand effects produced by the vastness of the structures he designs are commonly fortuitous and not the distinct aim of the designer; their beauty (if any) is that which grows out of the fitness of things, the perfect adjustment of the means to the end desired, in the absence of which conditions real beauty is non-existent, and, like faith without works, is dead.

One good result which might have been expected to issue from the temporary cessation of the battle of styles amongst us, consequent upon the benign influence of good Queen Anne, was the increased study of comfort and convenience irrespective of eclectic considerations, the element of picturesque grouping atoning for all irregularities in design. Certainly design is now unfettered by symmetrical rules of sentimental proportion or balance of ornamental associations either of gothic or classic origin. It is well that the public should understand this, and be able to rest content that, when an architect is employed to build a house, it will not be necessary to call in the sanitary officer in order to be sure that it is properly lighted, heated, drained, and ventilated. I do not say that this has never been necessary, for I cannot forget how the artistic nature of a late popular and justly esteemed young architect rebelled against the prosaic duties of the hour. Once when I was with him, a letter came from a client complaining of some defective piping, &c. "Pipes," said he, "what do I know about pipes? Let him send for his plumber." But this indifference is becoming less every day.

British Sanitary Archæologia has yet to be satisfactorily compiled. Prior to the Great Fire of London, no provision was made for the conveyance of the storm waters by underground sewers, and the waters found their way to the river by natural means. In an Act of the 19th year of Charles II. for rebuilding the city, the City Commissioners of Sewers were first appointed, but they were entrusted with this power for seven years only. By an Act in the seventh year of Queen Anne, they were made perpetual. It is to be regretted, however, that the storm waters were ever mixed up with the house drainage. In 1834, a civil engineer stated, before a Parliamentary Committee, that

with them, and ultimately the ministers of other congregations were included therein; the object being to make it as much a district matter as possible. Their first care was to ascertain the real state of the district in a sanitary point of view. The City Missionaries, Messrs. Genever, Brown and Thomas, assisted most energetically in obtaining this information by means of a house to house investigation, noting down from the lips of the occupants and from their own observation the various annoyances to which they were subjected. From the reports of the City Missionaries, Mr. Robins and Mr. Russell drew up a statement showing the then present state of the district, and the great need that existed for some interference on behalf of the poorer classes. This statement was printed and circulated among the higher class of residents throughout the district. The Incumbent also forcibly appealed to his congregation to support the Board by their liberal contributions, and on three successive Sundays he appropriated to its funds the collections made in the boxes at the church doors, which, added to subsequent donations, enabled the Board to proceed to the appointment of an Inspector, and from his appointment the aggressive operations of the Board commenced." —*Extract from "General Report," November* 1854.

when in the previous year some French engineers were sent over to England by their Government nothing seemed to attract their attention more than the sewers of London, the drainage of Paris being then under consideration. Their ideas of the proposed drainage never extended to more than taking away the surface waters, and they seemed astonished when he told them that the water from our lowest cellars drained into those great sewers. The state of Paris before the Second Empire is well known, the foul drains that ran upon the surface of the ill-paved streets, and the abominable stenches, everywhere proved the want of sanitary reform; and Paris is still anything but sweet.

Illustration No. 61 is the copy of a design for draining Paris, projected by the architect Patte, and published in the year 1769. A vast sewer in the centre of the road is ventilated by vertical shafts over it, and has ledges on either side, above the springing of the lower semi-circular inverted arch, for the carriage of water pipes. The road gullies, house wastes, water-butt overflow and water-closet soil, all descend direct to the sewer. The description will be best given in Patte's own words:—

"La propreté des villes s'est toujours exécutée le plus maladroitement, par rapport à la salubrité de l'air. Je ne connais dans l'antiquité que les Romains qui aient fait des efforts, pour opérer avantageusement le nettoiement des rues: encore y furent-ils nécessités par la position même de Rome, qui comprenait dans son enceinte sept montagnes. Dans l'impossibilité d'étendre leur ville au milieu des vallons qui formaient autant de ravins, ces peuples furent contraints de pratiquer pour reçevoir les eaux, ces cloaques ou aqueducs souterrains dont on voit encore aujourd'hui des ruines (ce n'est pas qu'on n'ait construit des égoûts souterrains sous une partie de plusieurs villes; à Londres entr'autres, il y a quelquefois un égout des deux côtés des principales rues, le long de chaque trottoir. Mais nulle part on ne les a disposé de manière à ne point infecter les rivières dans leur trajet à travers des villes; jamais ils n'ont eu pour but que de reçevoir les eaux des ruisseaux; et aucunement d'opérer le nettoiement des rues, le transport de leurs ordures, et de faciliter les réparations des tuyaux de conduite), et desquels ils se servirent en même temps avec avantage pour l'écoulement et le transport de toutes les ordures. Ces cloaques ne parcouraient pas toutes les rues, ils étaient seulement distribués dans les lieux les moins élevés de cette Capitale, et venaient tous se rendre dans un autre beaucoup plus grand, appellé *cloaca maxima*, qui se débouchait dans le Tibre entre le mont Aventin et Palatin. On avait réuni sept sources ou sept ruisseaux dans de vastes réservoirs, qu'on lâchait fréquemment dans ces voûtes souterraines, pour les nettoyer et entraîner successivement tout ce qui y avait été jeté. . . . .

"Il ne s'agirait que de saisir l'esprit du procédé des anciens Romains, et d'appliquer à la totalité d'une ville, ce qu'ils firent pour opérer la salubrité d'une partie de la leur; c'est-à-dire, qu'il n'y aurait qu'à pratiquer sous toutes les rues, des aqueducs souterrains, capables non seulement de servir aux transports des ordures et à leur écoulement sans embarras, mais encore d'assurer la solidité des conduits et de favoriser leur entretien. Voici comme j'imagine que l'on pourrait opérer la réunion de ces différents objets: Ce serait de placer sous le milieu des rues, à cinq pieds au-dessous du pavé, un aqueduc soûterrain d'environ six pieds de largeur sur sept pieds de hauteur. On assurerait la solidité, en construisant sa partie inférieure en forme de voûte renversée avec des claveaux de grès ou de pierre dure, et en faisant sa partie supérieure aussi voûtée, soit en pierre de meulière, soit en petits moellons de roche avec des chaines de pierre dure, de douze pieds en douze pieds. . . . D, fait voir en profil toute sa construction. . . . .

"A droite et à gauche, et à quatre pieds du fond de l'aqueduc, on pratiquerait deux banquettes, F, F, en saillie, d'à-peu-près quatorze pouces de largeur, sur lesquelles seraient placés deux tuyaux de fer fondu 5, 6, qui conduiraient les eaux des différents réservoirs, provenant soit de la rivière, soit de diverses sources, dans les fontaines publiques, et dans les maisons, à l'aide de petits conduits de plomb, soudés aux gros tuyaux vis-à-vis des endroits en question. . . . .

"Il est évident qu'à l'aide de notre arrangement, il ne serait plus besoin, pour faire les réparations des tuyaux, de dépaver les rues et d'embarrasser la voie publique. Par dedans l'aqueduc souterrain, on remédierait avec facilité à tous les accidents qui surviendraient. . . . .

"Par le moyen de nos aqueducs souterrains, il est encore aisé de réformer les fosses d'aisance qui causent dans les maisons d'une ville une infection journalière, et empestent tout un quartier quand il s'agit de les vider. Il n'y aurait qu'à établir toujours les latrines au rez-de-chaussée, et tenir leur fosse peu pro-

fonde en forme d'égout : alors en plaçant dans le fond en tuyau assis solidement, et disposé en pente vers l'aqueduc, les matières y seraient conduites à mesure. Dans l'intention de précipiter leur écoulement, il faudrait faire en sorte de diriger à travers les petites fosses en question, toutes les eaux d'une maison, celles des toits, celles qui proviendraient des cuisines, celles des cours et autres. Par ce procédé ces endroits seraient sans cesse lavés. . . . . Il est à observer que l'issue des tuyaux de ces fosses dans le cloaque serait placée dans le socle des banquettes qui portent les conduites d'eau. . . . . On voit dans la Planche le profil d'une latrine : S est le siége ; T est la fosse ; X est le tuyau destiné à conduire les matières dans l'aqueduc, lequel est assis sur un petit massif de maçonnerie ; V est un petit réservoir occupant le dessus des latrines, lequel peut être rempli naturellement par les eaux des toits, à l'aide d'un tuyau de communication avec celui ce conduite, &c. Cette eau servirait à lacher successivement dans la fosse T, pour précipiter l'écoulement des matières. Enfin, Y est un tuyau destiné à diriger l'eau de la cour à travers de la fosse."[1]

Public Sewerage and House Drainage.

There are two distinct systems of sewer construction, broadly distinguished by the phrases, *sewers of deposit* and *sewers of suspension*, both having reference to the water carriage of excrementitious matter. The former is adopted in many great towns, and does not necessarily provide for the immediate removal of the soil from houses except in times of storm or very wet weather. At other times a system of flushing more or less intermittent is involved, owing to the absence of sufficient water for the carriage of the soil accumulations and refuse. The latter is adopted in some provincial towns, and requires the removal of the soil at once at all times of the year, or at the very least before the solid matters in suspension have had time to enter into that putrid state when sewage gases of a most deleterious character are generated within the sewer. Obviously the former system is one which by providing for occasional storm waters, or heavy rains, over a large surface of land, as well as the ordinary house sewage, necessitates the construction of vast cavernous sewers, which in dry weather, from the absence of adequate rain-fall and of sufficient flushing arrangements, constitute sewers of deposit, the emanations from which are often so deadly, owing to the insufficiency of ventilation, that disease and death are pent up within them, ready to find a way through every aperture into the dwellings of rich and poor alike, so that the prince and the peasant are equally endangered by living in houses or hovels whose drains are in direct communication with the sewer, unless those precautions are taken which it is the business of Sanitary Science to discover and to enforce. Not long since in the City of Paris it was reported that five men were killed outright through entering an insufficiently ventilated sewer—simply poisoned by the malaria. The latter system is one

[1] See Chapter I., "Considérations sur la Distribution Vicieuse des Villes, &c." in the *Mémoires sur les objets les plus importants de l'Architecture. Par M. Patte, Architecte de S.A.S. Mgr. le Prince Palatin Duc régnant de Deux-Ponts.* Paris, 1769.

Further references to the illustration, not mentioned above, are—" B, B, Chemins le long des maisons pour les gens de pied, séparés chacun de la chaussée par un ruisseau, F. C. Bornes placées près des ruisseaux en deça de la chaussée, pour mettre les habitants à couvert de tout accident de la part des voitures ; 1, 2, colliers de fer, dans lesquels sont passées des perches, 3, pour soutenir une banne, 4, de toile cirée, lors des mauvais temps. E, Trou en forme de puits, pour recevoir toutes les ordures des rues. G, Direction d'un des conduits des ruisseaux dans l'aqueduc. Z, Fontaine domestique destinée à rassembler l'eau de pluie pour la boisson. &, Tuyau de conduite dirigeant l'eau des toits vers la fontaine, pour la remplir quand on le jugerait à propos."

which provides a separate sewer for the storm waters, or leaves them to take care of themselves and find their own way into the rivers and the sea, and thus necessitates the conduct of the house drainage only in comparatively small pipes, the smallness of the bore concentrating the stream of water which carries with it the soil held in suspension along the narrow channel provided. The constant flushing of such sewers is an easy matter, and an example of its apparent success as a system has recently been the subject of rejoicing at Memphis in the United States of America, concerning which it may suffice to say that designs were prepared on both systems, the first providing for the storm waters with sewers from 1 foot to a 7-foot outlet main. The second design, which has been adopted, has pipes only ranging from 6 inches to 20 inches at the outfall. 3000 feet length of 6-inch sewers communicate with 8-inch branches falling into 12-inch and 15-inch sewers, meeting and ending in the 20-inch outfall pipe. At the head of each line of sewers is a Field's flushing tank, from 120 to 150 of which will flush the sewers daily or twice a day with 100 gallons of water at each automatic discharge. In connection with this system are 4-inch house drains, on the back drainage plan, no drains being allowed to pass under a house.

It is well known that in London a system of sewerage prevails which, despite many excellences as a scientific work of modern engineering skill, nevertheless entails the necessity of recognising the insanitary condition of the main sewers, aggravated of late years, not merely by the increase of the population but by the fact that, simultaneously with the construction of these sewers, cesspools were abolished, and all solid as well as liquid matters now find their way into the main sewers. This condition of things, resulting in the conduction of sewer air into the dwellings of the people, affects not merely the air but the cistern water supplied to the houses; and the architect has further to consider what may be the effect on the health of those who drink the water thus impregnated with a poisonous gas, considerations which necessitate special contrivances to prevent the possibility of any contamination of the air, or of the water, by the emanations from sewers or from foul house drainage.[4]

[4] The following extracts are from a Report upon the Metropolitan Sewers, made by Mr. Edward Monson, Assoc.-M. Inst. C.E., for the information of the Society of Arts:—

"In accordance with your instructions, I have made enquiries into the condition of the metropolitan sewers, and beg to report that I find the subjects given me for enquiry are so large that I have been unable to deal with the whole metropolis. . . . . The subjects given for investigation are:—First, as to the extent of the existence of sewers and drains of deposit in the metropolis. Second, their effects in the development of the gaseous products of decomposition. Third, the mode of cleansing the sewers. Fourth, the defects in sanitary science and art evinced in their construction and working.

"I.—From the enquiries I have made, extending over a period of twelve months, I find that the sewers of the metropolis are, in many cases, sewers of deposit, and not constructed on the self-cleansing principle. In proof of this, I need only point to the fact that a great number of men are required by the Board of Works and the various vestries to keep them open and in working order. The low-level sewers are constructed at a level sufficiently low to pass under the existing outfall sewers; they have no available outlet, except by pumping. In point of fact, they are not sewers at all, but sewage tanks, adits, or reservoirs, and hold the supply of sewage for pumping. They are the sludge chambers of the district and receive the filth of the adjoining parishes. They are elongated cesspools and unquestionably sewers of deposit. Not being in duplicate, and having no outlet except by pumping, they are never entirely emptied. The sewage thus becomes putrid, and the offensive smell from these sewers is the subject of frequent complaints. . . . .

We may now consider:—1. The common defects in sanitary construction. 2. The remedies generally available.

To describe in very great detail defects in sanitary construction is not now necessary;

In some places the old flat-bottomed sewers, originally constructed for surface water and rainfall have been utilised for the conveyance of sewage. These sewers, as a rule, are not self-cleansing, but sewers of deposit —a natural consequence of the sewage being spread over a wide surface and retarded by friction. . . . . Again, some of the large old sewers are not self-cleansing, but sewers of deposit. A flusher has told me of a case where, from subsidence or otherwise, the sewer bottom is not regular, and the sludge lies in pot-holes, to the depth of a foot or eighteen inches. . . . . Some of the smaller sewers belonging to the vestries are not self-cleansing, and being inconvenient to work in, and difficult to inspect they get neglected.

"II.—Sewers of deposit mean the decomposition of putrid matter, and the constant formation of sewage gas. Sewage gas being constantly formed, it constantly escapes through the ventilators in the streets, and through any untrapped openings. In consequence of the traps being left off, through the carelessness of servants, it is discharged into dwelling-houses, and finds its way into bedrooms through the open joints of the rain-water pipes. Again, during a storm, the low level sewers are filled and the sewage heads up. As the sewage rises, the sewage gas becomes more and more concentrated, and if sufficient means of ventilation are not provided, it is forced up the drains and discharged into dwelling-houses through the traps.

"III.—The sewers not being self-cleansing, it is necessary to employ manual labour to keep them open and in working order. So great is the deposit, that for the main sewers alone, 130 men are constantly kept by the Metropolitan Board at this work, and the sewers for this purpose are divided into six sections, three on either side of the river. The men are called flushers, and are paid 4*s.* 6*d.* a day. They are divided into gangs of about five men. To every gang there is a foreman, and to every twenty men there is an inspector. The open sewers are cleansed out about once a year, the other sewers in rotation, and as required. The sewers are flushed by means of a dam board, which is constructed to fit the sewer, and has a hole in the shape of a V cut in the lower edge. The dam board being fixed, the sewage heads up, and rushing through the aperture in the lower edge of the dam board, stirs up the deposit and separates the drift from the organic matter. The organic matter is flushed on, and at length discharged into the Thames. The drift and other inorganic matter is conveyed in barrows to the man-holes, brought to the surface and used in road-making, or sold to jerry builders for about sixpence a load. My informant says, that 'Vestries are not obliged to construct catch-pits, and slush is frequently forced down the gullies and into the main sewers to the extent of two or three hundred loads of deposit at a time.' The ventilation of the sewers is by open gratings, and, as a rule, no deodorants are used. Sometimes there is inflammable gas in the sewers, and, on more than one occasion, it has been fired by the light which the men carry on their heads when at work, and the men have been injured. Recently, at Wandsworth, two flushers were suffocated whilst working in the sewer, owing to a discharge from some chemical works; two gangs of men had previously refused to work in the sewer. The Main Drainage of London has greatly improved its sanitary condition, and given an improved outfall to the low-lying districts; and, whilst the main sewers were being constructed by the Metropolitan Board of Works, the various vestries and district boards have spent large sums in the construction of self-cleansing sewers of the egg-shaped pattern. The vestries also employ flushers to cleanse the old flat-bottomed sewers. In the Westminster district five flushers are employed by the district board, and they work by day; they are expected to keep the sewers clean, and are not paid for overtime. The wages are 1*l.* 5*s.* per week and two pairs of boots per year. Deodorants are used in special cases. My informant says that 'the deposit comes chiefly from the macadam roads. The sewers are mostly egg-shaped, the inverts of the flat-bottomed sewers having been taken out and the sewers altered by underpinning. The gullies are trapped and the sewers ventilated in the middle of the roads. The pipe sewers are kept clean by occasional flushing and may be called self-cleansing. The sewers never head up now and the main drainage is a decided advantage to this district.' In the St. James's district there are about two miles of main line sewers in Oxford Street, Regent Street, and Piccadilly, and there is a local sewer over the main line sewer. Three flushers are employed by this vestry; the foreman has 30*s.* per week and the others 1*l.*; the hours are from six to half-past five o'clock, and if additional flushing is required it is done by contract: Many of the sewers in this district are 5 feet 6 inches by 3 feet, the Westminster pattern. Upon the inverts of some of these a pipe was formerly laid for the conveyance of sewage, but it became silted up, and the surveyor has had all the pipes taken out and the sewers reinstated. The fat and

so many pamphlets have appeared, and so many books have been written about them, that a very short summary will suffice. Indeed that summary is provided in a small volume prepared by Mr. Teale, the Surgeon to the Leeds Infirmary, entitled "Dangers to Health,"

other stuff coming from the clubs consolidates in the sewers and is a great deal of trouble. There are fourteen miles of sewers, but it is the three miles in the neighbourhood of Piccadilly upon which the men are principally employed, and their work is greatly facilitated by the rats and by the vagabonds who go down into the sewers to see what they can find. This district is said to be much improved by the Main Drainage. A table, showing the various sewers, hangs in the surveyor's office. In the district of St. George's, Hanover Square, the number of flushers employed is six. The wages of the foreman are 25*s.* and the wages of the men 24*s.* per week; the hours are from seven to four o'clock. The men work during the day, and it is estimated that they bring to the surface 450 cubic yards of deposit in a year, which is removed at 4*s.* per cubic yard; it consists chiefly of drift and macadam. The flushers are not troubled with fat in the sewers. The population resides only during the season. There are about 52 miles of sewer, and, as a rule, they have a good fall, but in Belgravia it is bad. They are ventilated in the middle of the streets and the gullies are trapped. The old sewers are of the Westminster pattern, and the new ones are egg-shaped. The inverts of the old sewers have been taken out and replaced by inverts of the egg-shaped pattern. There are very few pipe sewers in the district. The Metropolitan Main Drainage has not made it much better, except for the purpose of letting off the rainfall.

"IV.—The disposal of the sewage of London has always been a matter of difficulty, and this difficulty has not been removed by the present system of drainage. The brickwork has been executed in the very best manner, and the pumping machinery is a wonderful specimen of mechanical skill, but still, so far as regards the disposal of the sewage, the works are a failure. It is disposed of by discharging it into the river sludge, and all without any treatment whatever. The damage to the river is at present disregarded, and no account is taken of sewage mud and filth which is being constantly cast upon its banks. The old plan was to store the sewage in cesspools constructed in yards, gardens, and under houses; it was next turned into the Thames, and it is by the present system moved on and turned into the river lower down. The nuisance is recurring. It has been removed, but not abated. It will crop up again and again, and this is a grave sanitary defect. We are told that the sewage not only does no harm, but from the improved scour of the river it actually does good. The fact is that the streams used to flow into the river above bridge, are now passed through the main sewers, and this large body of water being diverted from its natural course, and poured into the river at a new point, produces a scour at the point of discharge, but the soil thus removed is deposited elsewhere along with the filth from the sewage. The works are defective in not being self-cleansing. It must be a wrong system which requires so much labour to keep the sewers open and in working order, and which depends very much for its efficiency upon manual labour. In the intervals between the visits of the flusher, the sewers must be left to themselves, and a deposit must be constantly forming, and the organic matter constantly decomposing and liberating noxious gases which pollute the air. The flushing may be well done and well looked after, but still, with sewers which are not self-acting, these things must happen. If a system of self-cleansing sewers had been constructed (and all main sewers ought to be self-cleansing), so many flushers would not be required, the sewage would not have time to decompose, and the formation of sewer gases would, to a considerable extent, be prevented. The washing of the sand out of the sewage by the flushers is a novel and brilliant idea, but this might be accomplished at much less cost. The drift, which finds its way into the sewer, ought to be excluded, and after it has entered the sewer, it might be intercepted by properly constructed catch-pits. The flat-bottomed sewers might be altered so as to be self-cleansing, and inequalities in the sewers might be removed by reconstruction or lining. The decomposition of the sewage might, to a considerable extent, be prevented by a proper deodorant skilfully applied. The metropolitan system of drainage, in its present form, is not complete. Much has been done, but still there is much to do. The District Boards are fully alive to the advantages of self-cleansing sewers, and in many cases the old sewers have been taken up, and an improved form substituted. The water-courses, which have been most improperly diverted from the river, ought to be reinstated; the sewage ought to be purified before turning it into the river: the removal of filth from the sewers, to a considerable extent, ought to be effected by mechanical means, instead of by manual labour The sewers require to be rearranged, so as to make them self-cleansing. The drainage of London, which is upon the combined principle, provides for only a quarter of an inch of rainfall in twenty-four hours, but, during a thunderstorm the rain falls at the rate of two or three inches per hour, and at times, steadily, two inches in twenty-four hours. It will thus be seen that the sewers are totally inadequate to carry off the rainfall, and the lower parts of the district are sometimes flooded from this cause. If the separate system of drainage

a book which contains 55 page-illustrations of domestic sanitary defects and their obviation. A grim humour pervades them all. The book is dedicated by the author to his medical brethren, and is intended to afford graphic illustration of the dangers of carelessness in sanitary matters, and to give at a glance to the uninitiated a clue whereby the existence of defects may be discovered and amended. These defects consist not only in those things for which an architect might be blamed, but in the faulty construction and workmanship of the work done by the artisans employed—defective jointing of bad iron, lead, or stoneware piping, false levels and bad laying of drains, perverse connections on the wrong side of the traps, contaminations of water supply, ill-supported vertical soil pipes, and the thousand-and-one evils growing out of the want of properly educated and properly trained workmen and foremen. The City and Guilds Institute for the advancement of Technical Education has done wisely by introducing the subject of "Plumbers' work" into the new list of Technological Examinations. Happily such common defects in drainage construction as were, till lately, existing in Boston, United States of America, and recently illustrated in the Society of Arts' Journal, are daily becoming less common in London, but as Colonel Waring, the engineer of the new drainage works at Memphis, states, when reporting on the condition of Washington, "the particular idea of the size of a drainpipe required to receive the drainage of a house, or of a number of houses, is strangely in error. A pipe 6 inches in diameter, having an inclination of 4 inches in 100 feet, or less than half an inch in 10 feet, has a capacity of discharging nearly 200 gallons per minute, say 12,000 gallons per hour, or averaging between 3 and 11 in the morning 30,000 gallons. Such a pipe, then," says he, "even at such a slight inclination would be adequate for the removal of 150,000 gallons per day. If each household averages six persons, and if the daily consumption is even 50 gallons per head, the service would suffice for 500 houses, or supposing the sewer to run half full, for 250 houses." These figures are attested by facts collected by Colonel Waring, concerning the passage of water through existing pipe-drains elsewhere, which had been carefully gauged. Mr. Chadwick confirms these statements, and states that his experience coincides therewith. It will thus be seen that certainly no single house needs a larger outfall pipe than 6 inches diameter. In some provincial towns it is limited to 4 inches, where proper flushing arrangements exist.

were even now adopted, the capacity of the sewers for removing excrementitious matter and foul and waste water from the district would be greatly increased. At the present moment, there is a difficulty with regard to the drainage of several towns situate on the banks of the Thames. Some of these towns are intimately connected with the metropolis for drainage purposes; they have been heavily taxed for drainage works executed within the metropolitan area, and they have a right of drainage into the metropolitan system. In reply to applications for that purpose, they are met with the remark, 'Oh, we cannot take you in, our sewers are not large enough.' Now, such a remark may be perfectly correct if it means that the sewers are not large enough to take in the rain water and the sewage also, but it is not correct to say that the sewers are not sufficiently large to take in the sewage of these towns. The western sewers, for instance, were constructed for this very purpose; if not, why were they constructed so large? First-class sewers to drain streets are ridiculous. The sewage for the western district at the present time is so small in quantity that if the streams were excluded the pumps would have comparatively nothing to do. If the agricultural drainage and streams were allowed to flow along their natural channels to the river it would reduce the expense of pumping, and the carrying capacity of the sewers for removing sewage proper would be so greatly increased that all the towns along the valley of the Thames might be taken, say, as far as Teddington at least, to the great benefit of all concerned."

Nevertheless, ignoring all progress, in the last edition of a justly esteemed Encyclopædia, at page 701, under the head of "Specifications" the bewildered student may read as follows:—

> "To execute proper barrel drains for draining the premises, as shown on the plans, to fall into a main sewer or cesspool as the case may be. The principal drains to be 18 inches, and the smaller ones 12-inch barrelled drains, with half-brick rims, and the lower half of each drain composed with pure Parker's cement. . . . N.B.—We have here described the sizes of drains as for a moderate-sized mansion. We might say that 30 inches is the maximum diameter likely to be required for a large building, and none should be made less than 9 inches wide with half brick sides, three courses high, curved top and bottom."

I may add that Professor Henry Robinson gives the following rule for calculating the flow in sewers:—

x = Area of sewer ÷ the wetted perimeter in feet.
f = Fall in feet per mile.
v = Velocity in feet per minute. $v = 55\sqrt{x \times 2f}$
a = Area in square feet. $c = v \times a$
c = Cubic feet delivered per minute.

And now with regard to my second point: the remedies generally available for the reduction of the sanitary evils we condemn. In the first place I will draw attention to the practice of specialists, whose system is more or less in harmony with the previous practice of those architects who have also given considerable attention to this subject. At the Annual Conference of the Society of Arts on the progress of public health, in June 1880, Sir H. Rawlinson stated that house drainage was at the root of all sanitary reform, and he was pleased to inform us that Lord Spencer had kindly permitted the inspection of the system of drainage adopted at his lordship's house at St. James's. Sir H. Rawlinson added that, at that moment, as far as his knowledge extended, it was the most perfectly drained house in London or elsewhere. The principles upon which this mansion and many more, including Mr. Edwin Chadwick's at Mortlake, have confessedly been drained, will be found laid down by Sir H. Rawlinson, of the Local Government Board, in his "Suggestions as to the preparation of district maps, and of plans for main sewerage, drainage and water supply." The engineer employed was Mr. E. F. Griffith, one of three gentlemen—engineers and specialists in sanitary matters—who have devoted themselves to sanitary engineering, and hold a representative position therein; and in the report of the Meeting of the Sanitary Section of the Society of Arts, in June 1880, the evidence of Messrs. Eassie, Rogers Field, and E. F. Griffith is given in full. Mr. Griffith thus summarises the principles adopted by him:—

1. Communication between main sewer in streets and housedrain should be disconnected or severed by an open air space being left between housedrain and sewer.
2. The housedrain should be laid to such a fall as to be self-cleansing, free from deposit, and ventilated; besides which it must be air and watertight.
3. The soilpipe should be fixed outside the house and taken up full-size above the roof.

4. The wastepipes from the safes of all closets should discharge into the open air instead of into the soilpipe or D-trap.
5. Then there should be no means of drawing water from the cistern or cisterns supplying closets, other than through the closets.
6. The wastepipes from sinks, baths, lavatories, &c., should be trapped underneath, and made to discharge immediately into the open air over trapped gullies.
7. There should be no connection or branch with the main housedrain, where laid underneath the house, except outside the main walls of the building.
8. "Pan-closets" with "D-traps" should never be used, nor should D-traps be fixed under sinks, &c.

Then follows the description of the manner of applying these principles, and in answer to the question, "After your examination of an ordinary London house, what course do you usually recommend?" Mr. Griffith said:—

"If I am instructed to place the house in a thoroughly sanitary condition, I first make a plan of the house showing exactly how the new drainage can be laid, and then proceed to have all the old drains and contaminated earth removed. Unless absolutely necessary I never lay a new drain underneath the house. Should it be necessary to lay a new drain under the house, I use an iron pipe, laid perfectly straight from a disconnecting manhole constructed in the front area to a manhole in the back area. Between these two manholes the iron pipe is laid perfectly air-tight and water-tight, and no branch drain or wastepipe is discharged into this iron drain between these two points; besides which it is laid to a good fall, which will ensure its being self-cleansing. This iron drain is completely severed from the main sewer in the street by the disconnecting manhole, which is constructed in the front area. All the branch drains discharge into a manhole, and every pipe is laid perfectly straight from point to point, a manhole or turning chamber being constructed where a change of direction takes place. Every drain and wastepipe is so laid that, in case of stoppage, it can be cleaned out without opening the ground, removing the paving, or cutting about the walls either inside or outside the house; besides which every drain and wastepipe is thoroughly ventilated. I fix the soilpipes from the closets *outside* the house, and take them up full size above the roof. The closets would be fixed against outer walls only, and the soilpipes from them would discharge direct through the wall into the iron soilpipe fixed outside. In each closet some permanent ventilation would be made. The wastepipes from all sinks, baths, lavatories, &c., would discharge direct through the wall over the trapped gullies, or if above the ground level, into rainwater pipes, which would discharge over trapped gullies at the foot. The overflow from cisterns would discharge direct through the wall into the open air, so that in the case of the ball valve in the cistern being defective, the overflow water would immediately attract attention, and by this means prevent the waste of water which now often takes place, and, in many cases, continues for months without being remedied. The valve and wastepipes of the bath are made of such a size that whenever used, the housedrain will be flushed. The cistern or cisterns which supply the closets would be so made that no water could be drawn from them except through the closets, special reservoirs for the drinking water being supplied."

In answer to the question, "Why do you prefer cast-iron drains underneath the house?" Mr. Griffith replied, "Stoneware pipes laid on a bed of good concrete can be used, but there is more chance of leakage through defective workmanship than with cast-iron drains, with lead and yarn joints." And as to the *fall* to be given to drains, he said: "All housedrains should be so laid that they are self-cleansing, not when running half full, as is usually calculated, but when they have only about an inch of sewage flowing in them. I never lay a 4-inch drain to a fall of less than 1 in 30, a 6-inch to a fall of less than 1 in 40, and a 9-inch to a fall of less than 1 in 60. When these falls cannot be obtained, then automatic flushing arrangements should be made. All houses, in my opinion," concludes Mr. Griffith, "should be so drained that when water is discharged into the housedrain from any bath

or sink, closet, &c., the said water should be discharged in a body or volume so as to flush the drain."

The following is Mr. Griffith's description of the illustrations here given :—" It will of course be understood that these illustrations (Plates 62, 63) are purely typical and the conditions may vary greatly in each case which has to be dealt with. Fig. i. illustrates a case in which the drains are all outside the house ; a manhole or chamber is constructed on the line of drain both for the purpose of obtaining easy access to the drains in case of stoppage and for providing an 'air break' or 'disconnection ;' a section (to a larger scale) of this manhole is given by Fig. ii. The syphon-trap fixed in the side of the manhole next the sewer prevents, as a general rule, the passage of sewer gas into the housedrain, but if by absorption or otherwise the gas does find its way into the manhole, it is there so much diluted that if it makes its escape through the ventilator to the manhole (as may be possible in certain states of the atmosphere) it is quite harmless. Generally speaking, however, there is a strong upward current of air in the housedrain caused by the soilpipe being carried full size above the roof, as shown, in which case the ventilating openings to the manhole serve as inlets for fresh air. Fig iii. shows another and cheaper mode of making the 'disconnection' of the housedrain from the sewer. In this case, a special syphon-trap is fixed with a branch pipe carried to the surface as a ventilator. The principle is precisely the same as in Fig. i., and is equally efficient in one respect, but if at any time it becomes necessary to examine the drain the ground or pavement has to be opened up. Water-closets should always be situated against two outer walls if possible, and should have a small anteroom (which may be used as a lavatory) between them and the main part of the house. In a case where there are no windows near, it is sufficient to carry the soilpipe just above the eaves gutter. The closets themselves call for no special description, except that they should not have overflows, for two reasons, one being that defects in the water fittings are not so easily noticed, and the other, the danger of admitting foul air through the overflow pipe. Instead of the overflows, a lead safe should be fixed, and in all cases the waste from these should be taken direct through the wall. Plate 63 gives the method adopted for disconnecting sink wastes. The section, Fig. iv., shows a scullery sink on the ground floor and a housemaid's sink above ; a plan of the scullery sink is shown at Fig. vi., is fitted with a trap, and the waste (usually 2 inches in diameter) is carried to discharge over a stoneware gully fixed outside ; the housemaid's sink, Fig. vi., if on the ground floor, is dealt with in exactly the same way, but if on an upper floor, as shown, the waste is carried into a rain-water head, the downspout from which discharges with a shoe at the foot over a similar gully."

The evidence of Messrs. Eassie and Rogers Field coincided with that of Mr. Griffith in all material points, and to quote their opinion is the less necessary, inasmuch as Mr. Eassie has published a book on "Healthy Houses," of 250 pages, with 300 illustrations, which may be bought for a shilling ; and Mr. Rogers Field's practice is well explained in his pamphlet published by Spon, entitled "Bye Laws and Regulations with reference to House Drainage adopted by the Uppingham Sanitary Authority, and allowed by the Local Government Board, with explanations and suggestions." The following are the rules to be observed in the construction of all buildings erected under the Surveyors to the Office of Works and Public Buildings :—

1. All water-closets and urinals shall be constructed so that one wall at least of such closets and urinals shall be an outer wall of the building.
2. All soilpipes shall be carried outside the building and ventilated by means of pipes leading the foul gases above the highest point of the building, such pipes to be carried to points removed from chimney stacks.
3. Separate cisterns shall be constructed for the water-closets and for the general purposes of the building; no tap or "draw off" shall be affixed to any pipe communicating with a cistern supplying a water-closet or urinal.
4 All wastepipes and overflow pipes of cisterns shall terminate in the open air, and be cut off from all direct communication with drains.
5. Great attention shall be paid to insuring through ventilation in all rooms. Rooms so high that their ceilings shall be more than 2 feet above the top of the windows, corridors, staircases, and other open spaces, shall be specially ventilated so as to prevent the accumulation of stagnant air.
6. All main drains should, where practicable, be formed outside the building. In the event of its being necessary to carry a main drain underneath a building it must be trapped immediately outside the main wall, and a ventilating pipe must be carried from that point to the highest part of the roof, as under Rule 2.

These sanitary principles will be found variously applied by different architects, but not so generally as should be. A syphon-trap is usually put on the sewer side of the manhole, and no manhole should be without ventilation, both an inlet and outlet clear of accesses to the interior of house. But the iron door of the manhole should only possess an open grating, when situated next a blank wall clear of all openings or children's approach, lest they should receive or inhale the impure air as it escapes by the grating.

Mr. G. Godwin's valuable papers on Hospital Construction, twenty years ago, were greatly influential in bringing about the present improved system of hospital planning. His profusely illustrated little books entitled "London Shadows, Town Swamps and Social Bridges, Another Blow for Life," &c., have enlightened the public to the many trials of the poorer classes arising from their insanitary surroundings, and given an impetus to the work of various societies for improving the dwellings of the labouring classes. The late Mr. Henry Roberts's name must also be remembered with respect by all interested in this subject; his long connection with the late Lord Shaftesbury's Society, and the improvements made by him in cottage building and ventilation can never be forgotten. Mr. J. P. Seddon is the author of twelve Papers published in the *Architect* in 1873, under the title of "Sanitary Suggestions." He has also written Papers on "Sanitary Reports," "Cowls," "Water Supply Regulations," "Warming and Ventilation," &c., and his brother Major Seddon, a Royal Engineer, is too well known as an expert in sanitary matters to need further reference. Mr. Norman Shaw, R.A., has shown by what simple means sewer gas may be absolutely disconnected from our dwellings; his process is well described in a pithy pamphlet he has published, wherein he speaks of a little baby of his own, with which he is reasonably content after a trial of some five years. His plan is to use external stackpipes, open at both ends, for the passage of soil and

o' wastes, and he ignores and deprecates the intervention of all traps except one ͵een his disconnecting open-mouthed drain, hopper and the pipe leading to the ͵er. His answer to theoretical objectors is simply this: he does not find the evils ͵uggested to occur in his own house nor in the many buildings to which he has applied his system, therefore he supposes it answers. At all events it has the great merit of singular simplicity and inexpensiveness, and the worst that can happen is but temporary inconvenience. Mr. William White, F.S.A., has written several Papers on the subject, and a valuable contribution in form of a pamphlet, entitled "Domestic Plumbing and Water Service." Mr. Henry Saxon Snell has done good service by the conscientious manner in which he has worked out the sanitary contrivances which distinguish the various Metropolitan Workhouses erected under his superintendence. In the Parkes Museum may be seen his "Duplex lid" to water-closet fittings, an arrangement by which the purity of the air is secured within the apartment devoted to its use. He is also the inventor of an excellent hot-water stove, heated by the open fire of the room, a singularly happy combination, also exhibited at the Parkes Museum.

I have mentioned these few names because something like a crusade has set in, not only by specialists, but by associated societies, such as that founded in 1878, at the suggestion of Professor Fleeming Jenkin of Edinburgh, entitled "The Sanitary Protection Society." Professor Jenkin read a Paper at the Social Science Congress at Edinburgh, in which he stated that in consideration of an annual payment of one guinea a member obtained: 1st, a Report on the condition of his house; 2nd, inspection of alterations made; 3rd, an annual experimental test of the condition of the drainage system. It was a mutual system then confined to Scotland, and there were 500 members. The success of the Northern Society has led Professor Jenkin, who read a Paper at the Society of Arts on the subject, to establish a London Sanitary Protection Society, with Professor Huxley as president. There is yet another London Society called the "Sanitary Assurance Association," recently inaugurated at the Langham Hotel. The object of these societies is to bring the benefits of sound sanitary construction and design within the reach of the humblest householder.

With reference to the removal of excreta from buildings where no system of water carriage for sewage exists, I think it important to mention the inodorous system of cesspool emptying by steam, adopted in France according to a patented process, invented by M. Talard, and introduced into this country by Mr. Laurie of Twickenham. I was one of a large company of gentlemen interested in sanitary matters who witnessed at Kew the process of emptying a large cesspool in this manner. The whole thing was done in a few minutes without the least effluvia being observable, though effected under a hot afternoon sun. As described by Mr. Laurie the process consists in pumping the excreta by the natural pressure of the atmosphere into a receiver from which all air has been first exhausted and a vacuum produced—in short, it is done with "pneumatic despatch." A steam vacuum pump is attached to a small portable locomotive engine to exhaust the air from the receiver, the pipes between this and the engine never being so much as soiled. The receivers are made of light steel plates barrel shape, and of a capacity of about $3\frac{1}{2}$ cube yards; they are mounted on framework, on four wheels, being

easily moved from place to place by a pair of horses; each receiver is fitted with a glass indicator at one side to show how full it is, and has a large fullway valve at the lower end, to which the flexible tube is attached. On the cesspool being opened, a strong 5-inch flexible tube is plunged to the bottom of the contents, the other end of this tube being connected with the valve of the receiver; this has already been connected to the engine by a smaller tube from the upper part of the receiver. The engine being started the noxious gases are first extracted from the cesspool, passed through the furnace and burned; the air is then exhausted from the receiver, and on the valve being opened, the contents of the cesspool rush up through the galvanized iron connecting pipes, 6 inches in diameter, filling the vacuated receiver in about three or four minutes. The valve is then closed, the pipes are disconnected, and the receiver is taken away to be replaced by another, until the cesspool is entirely empty. It is obvious that at no time in the process is there any exposure of the excreta to the atmosphere. The receivers are either discharged into close barges for transit, or emptied into reservoirs, or run upon the land in the usual manner for fertilizing purposes. The secret of success, however, lies in the singularly simple yet perfectly air-tight system of joining pipe to pipe and to the receiver, occupying less than half a minute to adjust each joint; each length of pipe is capped at both ends when not in use, with a similar joint for securing same. In Paris the price paid for extraction is five francs per cubic metre or 3*s.* 6*d.* a cubic yard, or one-third of the cost of our present mode of operating in this country, which averages half a guinea a yard.*

WARMING AND VENTILATION.

I have now arrived at the second general division of my subject, namely, "Ventilation," with which I must associate "Warming," owing to their close relationship. As Professor Jenkin once remarked to me, the study and control of the *pressure* of the atmosphere, and not the temperature only, is the key to all sound ventilation. As this pressure is increased or diminished in its utilization, so is ventilation promoted or

* A description of the method employed in some of the *maisons-à-louer* recently erected near the Champs Elysées, for the separation of the liquid and the periodical removal of the solid matter was given in the *Builder*, November, 1877, in an article entitled "Paris after ten years," from which the following is an extract:—"This block of houses possesses three *fosses* or cesspools: and we had the honour of entering one while operations for which a *fosse* is specially intended were proceeding. First, an ordinary wooden door was opened; we found ourselves in a narrow lobby, and it should be understood that this *fosse* was on the same level as the stables and cellars. Then an iron door was opened, and some pains had evidently been taken to render the door air-tight. There was no offensive odour; instead of a pool of liquid, we stepped upon a clean cement surface. A large opening near the top of the vault faced us; it was the ventilator. Next to it there was a large pipe descending into an iron cylinder of portable dimensions, raised a few feet from the floor. From the cylinder another pipe descended into the earth, and it was connected with the cylinder by a guttapercha tube. This machine, of a frightfully primitive nature, acts in the following manner: solid matter, descending by the common pipe which receives the discharge of each floor, remains in the cylinder, at the bottom of which is a narrow, well-protected grating; through that all the liquid oozes, by means of the guttapercha tube, into the drains, whereby it is conveyed by the street sewers to the Seine, at a distance from Paris. Every two days this chamber is visited by the servants of the company—undertakers, or rather contractors, for this system of drainage. The cylinder, disconnected from the pipe descending from above, and the guttapercha tube before mentioned, is carried off on the shoulders of two men; another empty cylinder is put in its place. Such a *fosse* is simply a clean empty cellar containing in one corner the rough machine which we have described."

retarded. The right government and direction of the currents of natural atmospheric pressure is the business of scientific ventilation, which pressure is always in the direction of the least resistance. There is what is called natural and artificial ventilation. The former acts by the force of diffusion by winds and by the difference in weight in masses of air of unequal temperature. Diffusion is an insufficient agent in ventilation, but it penetrates stone walls and permeates the soil and helps to produce damp basements only to be overcome by concrete laid over the whole site of the building. But wind is a powerful ventilating agent, and finds its way everywhere. Märcker of Göttingen shows that it will penetrate through a loamy brick wall at the rate of 5-12 cubic metres per hour, when the difference in temperatures is 1° Centigrade. It is the unequal weight of atmospheres that gives rise to wind, and the pressure of dry cold air against moist warm air produces rapid interchange of cross currents and movements of the air largely available for ventilating purposes. The inequality of temperatures is a fruitful source of change in the air, and the direction of the forces produced by it is a necessary aim in ventilating processes. By a difference of temperatures of 70° inside and 40° outside (Fahrenheit), the air will force itself through a square yard of limestone wall at the rate of 10 cubic feet per hour. The preservation of the purity of the air about us is therefore as essential as that of the spring at its source.[6]

Dr. Parkes has shown in great detail the various sources of impurity to which the air of enclosed spaces is subject, and the particular diseases to which such impurities give rise. In our present enquiry, and as he suggests, it will be desirable to restrict the term ventilation to the removal, by a stream of pure air, of the pulmonary and cutaneous exhalations of men, and of the products of the combustion of lights in ordinary dwellings, to which must be added, in hospitals, the inevitable effluvia which proceed from the persons and discharges of the sick. All other causes of impurity of air ought to be excluded by cleanliness, proper removal of solid and fluid excreta, and attention to the conditions of surrounding dwellings. We have, therefore, firstly to consider what quantity of fresh air is required for the above purpose, and secondly the best method of supplying it. Assuming that we have succeeded in ventilating our drains and in excluding sewer gases from our buildings by the means and appliances already detailed, our first enquiry must be, what is to be the measure of the impurities to be removed? Taking the presence of carbonic acid as the index of impurity, Dr. de Chaumont has shown by experiment that the organic impurity of the air is not perceptible to the senses until the carbonic acid rises to the ratio of ·6 per 1000 volumes. At ·2 it is fresh, or not sensibly dif-

[6] TABLE showing pressure of wind per square foot at different velocities :—

3 miles an hour,	¾ of an ounce on each square foot.		7 miles an hour,	4 ounces on each square foot.	
3½ „	1 ounce „ „		10 „	8 „ „ „	
5 „	2 ounces „ „		14 „	1 lb. „ „	

TABLE showing passage of wind through walls. Märcker has given the following as the amount of air passing in one hour through a square metre of wall space, when the difference of temperature is 1° C.:—

	Cubic Metres of Air.		Cubic Metres of Air.
Sandstone	1·69	Tufaceous Limestone	3·64
Limestone	2·32	Loamy Brick	5·12
Brick	2·83		

fering from the outer air; at ·4 it begins to be close; at ·6 it is decidedly close, the organic matter being disagreeable; at ·9 it is very close, the organic matter present being offensive and oppressive. The Doctor has also prepared *tables* which show the deterioration of the purity of the atmosphere produced by the respiration of one man in rooms varying from 100 to 1000 cubical contents, and the amount of air necessary to dilute to the standard of ·2 for the first hour and for each succeeding hour, which tables are readily available in practice. The amount of air required to do this has been fixed at 3000 feet for each adult healthy person in an hour, and it follows that, the larger the air space, the less is the necessity for the frequent renewal of air, and the less the chance of draught. Thus a space of 100 cubic feet must have its air changed thirty times in the hour, if 3000 cubic feet of air are to be given; while a space of 1000 cubic feet need only have it changed three times in an hour for equal ventilation. Every foot of gas consumed is equivalent to the vitiation of the air produced by the respiration of one person. The difficulty of thus changing the air without draught is, however, very considerable, and Dr. Parkes observed that "*a change equal to four or three times per hour is generally all that can be borne under the conditions of warming in this country.*" In practice the change made rarely exceeds 750 cubic feet per head per hour. It is obvious, therefore, that warming the incoming air is a necessity in cold climates like our own; and consequently the principles of warming and ventilation are too intimately connected to be completely studied or applied alone. Changing the air of a room is not the less necessary because the cubical space included within its walls is large; the largest space can only provide sufficient air for a limited time. Even in a space of 10,000 cubic feet per head, the limit of admissible impurity would be reached in three or four hours; after which the same constant hourly supply of 2000 or 3000 feet would be as necessary as in a space of 100 cubic feet. Obviously it is not onlyimportant that the air should be changed, but that that change should be for the better, by being drawn from a pure source, and carried through clean channels.

Ventilation means passage for the wind, change of air, or to use an expressive Americanism, atmospheric recuperation—both a way in for the air, and a way out for the same, which is the sole means of changing it, in any place or building, and no recuperative process can go on without it. Some people would seem to be possessed with a belief in infinite atmospheric compression; that it is only necessary to let air into a receptacle and that it will continue flowing on for ever. But to take an analogous element, the difference between air and water is only in degree; and as the full receptacle will hold no more water, so the vessel filled with air can take no more without unnatural compression. The temperature determines its bulk, and if equals be added to equals the wholes are equal. Airs of equal temperature are stagnant whether pure or impure; it is the ever varying temperature that chiefly constitutes the motive power and creates currents by varying pressures. As the difference in weight and temperature of the all embracing atmosphere in which we live and move and have our being gives motion to the winds, so wherever the winds are excluded from the interior of any place or building, an artificial difference in temperature becomes the needful provocative cause of movement through the inlets and outlets provided.

Natural ventilation is, then, the simple process of mingling the external with the internal

atmosphere of a building. Scientific ventilation is one and the same thing, but with this difference, that in the former case it is free to mingle or not as it pleases, and in doing so to create many inconveniences; in the latter, direction is given to currents of air produced by their interchange, and a healthy commingling of the oxygen with the carbonic acid gas is secured without the dangerous and disagreeable accompaniment of draughts. In short, the business of ventilation is to direct the pressure of the currents of air admitted and required to overcome its stagnation, under conditions where no draught is admissible; and to do this by mechanical appliances for the introduction and withdrawal of the air directed by the scientific apposition and control of varying temperatures. With the thermometer for measuring the temperature of the air, the hydrometer for testing its humidity, and the barometer for determinating its weight, we have the means of estimating and testing by experiment the pressure of the atmosphere in any direction. The measurement of the force of the currents of air produced by the difference of temperature, &c., existing between the external and internal air of a building is accomplished by the use of the anemometer or manometer. The natural process by which the temperature of the air is raised is twofold—by radiation and by conduction. Radiated heat has the peculiarity of passing directly through any intervening space or air without parting sensibly with its heat, and warming the first obstacle to its passage, such as a wall or window, with which it comes in contact. Conducted heat, on the other hand, is the warmth given off by any surface by direct contact with any substance, whether air or otherwise. The sun shining from its distance cannot part with any conducted heat, excepting the minute quantity given off by its rays to the dust in the air when passing through the same. It therefore heats practically by radiation alone, the warmth passing into the earth, and from that being given off gradually to the surrounding atmosphere—hence the difference of temperature in the sun and in the shade. In the case of open fires nearly the same result is attained, though at great outlay in fuel. The conducted heat of the fire passes into the air escaping up the chimney, and is lost for heating purposes, while the radiated heat alone is available for raising the temperature of the room; this warmth first passes into the outer surfaces, and is then given off by them by conduction into the atmosphere. Radiated cold from the outer surfaces, which is the chief source of the feeling of cold, is thus avoided, and a pleasant and agreeable result is quickly attained. Artificial heating, on the other hand, inverts the above principle by employing hot surfaces placed in immediate contact with the atmosphere. These, though giving off a certain proportion of their heat by radiation (which proportion increases with their temperature), yield the greater quantity by conduction to the surrounding air, which in turn gradually warms the enclosing walls, &c., instead of, as before, first warming the walls and then the air. The moisture contained in the air, or which should be contained by it, varies directly with its temperature, and when the atmosphere is violently raised in heat without provision for the proper additional proportion, it will seize on any moisture within its reach, causing a dryness of the skin, drawing the woodwork in the building, and producing other disagreeable effects. This is another reason why an Englishman's instinct leads him, while ignorant of the cause, to hold to his open fire. Draught is, however, an inconvenience inseparable from the use of open fires in unventilated rooms, especially where they are placed opposite the doors, since

they draw large quantities of air across the floor, and pass it up the chimney: to reduce the evil they should be placed side by side, and if this were carried into effect far less would be heard of cold feet. Cleanliness is a virtue for which the open fire is not usually praised, whereas, as a matter of fact, it is far cleaner in its use than any means of heating by conduction. The latter, circulating the air and always in the same lines, causes the dust particles to settle over the whole surface of the walls and ceiling, and gradually to discolour everything, whereas in the case of the open fire, where the upper stratum of the air is uniform in its motion, this is not the case. This phenomenon may be noticed at any vertical opening for emitting hot air. Thus at the New Station in Magdeburg there are, in the walls of the refreshment-room, four such openings about eight feet from the ground, and the wall above each one is ornamented from thence to the ceiling, some fifteen feet, with a broad black streak produced solely in this way, the sooty particles in the air being drawn towards the stream of air rarefied by heat and settling on the walls. With justice, therefore, an Englishman may love his open fire, the comforts of which cannot be denied, or its advantages disparaged; but it is practically impossible to adopt it in all cases. It is not inexpensive either in first cost, when all its adjuncts, in the shape of chimney breasts, mantel-pieces, stoves and hearths are taken into account; when adopted, as a rule, it is only used for heating a few particular rooms (the rest being left cold) and it heats these at a great outlay of fuel. A German, Russian or Belgian with his little fire in a colossal stove obtains five times the effect in half the time, more especially because he builds his house with some reference to the heat he loses by his outer surfaces. All the best authorities agree that no system of warming or ventilation is better for the absence of the open fire stove; it is not only the best heater by radiation, but it is the best ventilator by extraction as opposed to propulsion. Ventilation by extraction is produced by the application of heat either at the bottom or the top of a ventilating shaft so as to cause an upward current therein by the action of a fire, steam jet, hot water, or by a fan or screw used for the purpose of drawing out air. The constant current up a chimney when the fire is burning is in proportion, of course, to the size of the fire and the flue therefrom, but the usual current of a sitting-room fire of ordinary dimensions, as tested by the anemometer, is from three to six feet per second. If the area of the section where the anemometer is placed is known, the discharge can be stated in cubic feet; and even when there is no fire, the velocity of the upward current in the flue is usually from $1\frac{1}{2}$ to 3 feet per second. With an ordinary fire a chimney gives a sufficient discharge for four or five persons, above that number special appliances are required. The strength of the draught in the fire often causes down draughts in flues intended to act as outlets, unless there are inlets of area equal to or greater than the outlets and the smoke flue of the chimney. The ventilation of mines is carried on upon the same principle as this—that is, by lighting a fire at the base of the upcast shaft, by which the air is drawn down the intake shaft, and permeates all the workings of the mine in its endeavour to reach the vacuum formed by the rarefaction of the air in the heated upcast shaft. The skilfulness with which the air is directed may be judged of by the fact that in some mines a portion of the air makes a circuit of from thirty to forty miles before it can arrive at the upcast shaft.

Much difference of opinion exists both as to the size and the position of inlets and outlets. With regard to size, it is desirable to make each individual inlet opening not larger than from sixty to eighty superficial inches in area, or enough for three or four men, and to make the outlets about a foot square, or enough for six men. Distribution is more certain with several small openings variously placed, but the total area of inlets and outlets may be equal. The position of inlets should be opposite outlets, and on the same side of the room as the fire if there is one, or if the room is heated by a coil of pipes the incoming air should pass through the coil; if no means of heating the incoming air is available, the inlet should be in the upper part of the room and be directed towards the ceiling, or through shafts from the floor level known as "Tobin's" Cold air should either be heated on its entrance, or the inlets brought so near to the fire that it may draw from them without creating draught or checking the flow in the upcast extract shafts in the opposite wall. But both inlets and outlets may be at the bottom of the room, provided the fresh air is passed through the warming apparatus and the vitiated air is drawn through descending flues to the foot of a lofty shaft heated by a furnace; the lower the level at which the extract shaft enters the furnace the greater the extracting power, provided always the horizontal flue is not too long. The "Hygiastic" stoves bring in fresh air after passing it under the hearth and heated back and sides of the stove; the size of the grating is determined by the cubical contents of the room to be warmed and ventilated, and it is under control by an endless screw handle for opening and closing the louvres provided. I know no better exposition of the principles which should govern the design of such stoves than that given in Captain Galton's "Healthy Homes," illustrated by stoves of his own design, which have long been in use in military buildings. The introduction of air by vertical shafts suggested, nearly a hundred years ago, by a Mr. Whitehurst, is a sound principle eminently suited to the requirements of ordinary-sized rooms heated by the open fire grate only. A minimum of draught is achieved by it over any other system of direct introduction of cold air. So much has been written and said upon this so-called modern invention that I venture to print here some extracts from the pamphlet containing Mr. Whitehurst's ingenious suggestions, together with its title and preface:—

"OBSERVATIONS ON THE VENTILATION OF ROOMS; ON THE CONSTRUCTION OF CHIMNEYS; AND ON GARDEN STOVES. Principally collected from Papers left by the late JOHN WHITEHURST, F.R.S. London: Printed for W. Bent, Paternoster-Row, 1794. ADVERTISEMENT.—About ten years ago the late Mr. John Whitehurst, who died in 1788, had nearly completed for the press, a Treatise on Ventilation, on Chimneys, and the Construction of Garden Stoves, which was accidentally destroyed, and never afterwards replaced. The papers on which that treatise had been founded, were referred to me (R. Willan) for examination some time after his death. They consisted chiefly of remarks and memorandums relative to the subject, put down without order or connection. On a careful perusal of them, thinking the observations judicious, and not unworthy of public attention, I endeavoured to arrange them and to supply several deficiencies. This I was the better enabled to do, from having had frequent opportunities, during a long intimacy with Mr. Whitehurst, of learning his sentiments on the most material points. . . . The latest publication on the same subject is by the celebrated Dr. Franklin. His letter to Dr. Ingenhousz on the construction and use of chimneys affords many useful hints, but does not, I think, supersede the more enlarged plan of Mr. Whitehurst. Without derogating from the merit of Dr. Franklin's Essay, I may be allowed to observe, that we are in some respects indebted for it to Mr. Whitehurst, the Doctor having been first induced by him to attend to the subject of ventilation and chimneys, while on a visit at Mr. Whitehurst's house in Derby during the summer of the year 1774. . . . .

"CHAP. II. . . . . Let Fig. 11 represent the plan of a cottage, having one chimney C, one door D, and two windows A, B. Suppose first the door and windows to be air-tight, or so closely fitted,

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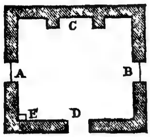

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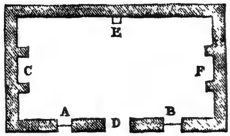

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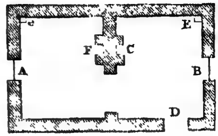
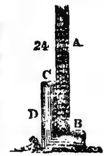




that they do not admit a quantity of external air sufficient to carry up the smoke in the chimney. The house will in that case be incommoded with smoke and stagnant air. If then a window or door be opened, the chimney obtains a supply of fresh air, and performs its office in carrying off the smoke properly. This circumstance points out to us a remedy for the defect, by making some convenient aperture into the house, which, however, must be done with caution, for if the opening is either at the door or window, the stream of cold air flowing from thence, will not only be unpleasant, particularly in winter, but very injurious to the inhabitants. What I should propose for the purpose, is an air-duct, three or four feet long, to be fixed in either corner of the room most remote from the fire, as at E, and communicating with the external air through the wall. The diameter of the duct must be from five to six inches. The air admitted by this means will ascend in a perpendicular direction to the ceiling; and being gradually diffused will soon acquire the temperature of the room. While this process goes on, no person within is sensible of it, nor is the flame of a candle in the least disturbed by it. At the same time smoke and stagnant air are effectually removed. If the air should be admitted near the fire, the chimney will act equally well, but the circulation through the room cannot be so perfect, for as the fresh air must take the nearest course to the chimney it would leave that which is contained in other parts of the room nearly quiescent, whereby it would become less fit for respiration.

"Let us next consider the consequences arising from two chimneys in one and the same room, as at C F, Fig. 12, other circumstances remaining as before.

1. If a fire be placed at C that chimney will not smoke, although the door and windows be perfectly close, because a supply of air must come from the other chimney.
2. If it were requisite to have a fire at F also, the smoke in that chimney could not ascend at all, on account of the current of air passing down it to supply C, or reversely if the fire were placed first at F, the chimney C would then smoke for the same reason.

"To remove the defect in this case without injuring the inhabitants, and to enable both chimneys to act well at the same time, it becomes necessary to apply an air-duct as in the foregoing instance, but in a different situation. Its capacity must also be enlarged, since two chimneys are to be supplied with air instead of one. A duct whose side is seven inches may answer the purpose, its area will then be forty-nine inches, or nearly double to that of the former, whose size was estimated only at five inches. The most proper situation for it is at an equal distance from each fire, as at E, because a stream of air flowing up from thence will have the greatest possible effect in ventilating the room. An air-duct at any of the corners might indeed afford a supply to the chimneys, sufficient to prevent them from smoking, but could only change the internal air partially. Let Fig. 13 represent the plan of a cottage, consisting of two rooms with the door D, and windows A B, close. A fire in the chimney C would not smoke since it must have a constant supply of air from the chimney F. But if the wind should happen to blow in the direction from C to F, the smoke rising from C would be carried down again with the air in F, and fill both the rooms. One air-duct might here also prevent the chimneys from smoking; but with a view to ventilation I should recommend two, situated as at E and e, which would always keep up a proper circulation of air through both the rooms.[7] . . . .

"Having provided for a general supply of air to the house, we should in the next place regulate the mode of its admission into each room separately, both above and below stairs, so as not to injure the architecture or to occasion any deformity, which may be done easily and without expense in the first construction of a building. I have employed in several instances the following method with advantage: I leave an open

[7] The form of the suggested air-duct is shown in Fig. 24 (see woodcut). A, represents an external wall: B, C, is the air-duct. Mr. Whitehurst further suggests that "the part C, D, should be a box of wood, the rest brick," and "if necessary an iron grate may be laid over the aperture B."

space between the upper part of the architrave, surrounding the door and the wall, on each side of the door, and likewise an open space between the casing and the lintel.

"The air then descends between the architrave and the wall on the outside of the door, and ascends between the architrave and the wall on the inside of the room. The current thus admitted rises in a perpendicular direction toward the ceiling, and acquires the temperature of the room, circulating through it imperceptibly to the inhabitants. At the same time it prevents any accumulation of stagnant air, and removes the smoke of candles, which is otherwise very pernicious.

"A similar mode of ventilation may be applied to all the rooms, however great their number, with the same beneficial effects. It renders the smallest apartments equally pleasant and healthful with the largest, and prevents the smoke from descending when the door shuts. In small rooms more especially, when they are furnished with an air-duct, it is proper to have the doors and windows as closely fitted as possible.

"Although the salutary tendency of this plan must be obvious when fully considered, there still remains a prejudice against it in the minds of the multitude. They obstinately maintain that the same injuries are to be expected from air admitted in this manner, as from the cold streams of it which usually flow into a room through the crevices of the door or window. However, the plan I propose is not recommended from theoretical speculation; it has sufficiently stood the test of experience, and to that alone we can properly appeal. Besides its own peculiar advantages, it effectually prevents those disagreeable sensations, occasioned by lateral currents of air, which chill the body on one side, while it is heated on the other, nor can its operation at all produce the same dangerous consequences, since the air introduced by it, being gradually and insensibly diffused, distributes a uniform heat round the room.

"I do not propose the method of ventilation above stated as the best in all possible cases. There is so great a diversity in buildings that a variety of modes may be adapted to produce the same effect. The application of the principles must then be regulated by circumstances, and by the discretion of the architect.

"A few general hints will, however, serve to facilitate the process. If the kitchen be connected with the house by a passage, or by any other means, it becomes necessary to apply an air-duct of considerable size for the use of that room alone. The area of the tube should not be less than 144 inches in a moderate kitchen; for if the chimney there have not a full supply independently it will draw air from some or all of the chimneys in the house.

"Different modes may be adapted to answer this purpose:—

1. A perforation of twelve inches square may be made in the kitchen wall near the bottom, to which a tube must be fitted as usual.
2. If circumstances do not allow of such an opening, air may be admitted by raising the sash five or six inches above the sill, and applying a board at about the same distance from the window to direct the stream of air towards the ceiling. This board should be one foot broad or somewhat more, and may be suspended on hinges so as to let down in the night if the window-shutters require to be then closed. In lofty kitchens, where there are small sashes, one of the windows is often hung upon an axis horizontally, so as to open or shut at pleasure by a line fixed to it. The inclination of the open windows affords a supply of air to the chimney, and defends the floor from rain; but it does not prevent the inconvenience from the wind blowing downwards into the room.

"In some rooms where it is not convenient to make a perforation, air may be admitted between the folding of the sash-frames by cutting away about the eighth of an inch from the frame, leaving the whole substance at each style. This is only practicable when there are shutters on the outside, and not on the inside of the window. For by inside shutters the current of air upwards is obstructed, whence it rushes through the crevices in various directions, and produces unpleasant effects."

Mr. D. O. Boyd has spent his life in trying to aid us in our endeavours to satisfy our clients and to please ourselves in laudable efforts to warm and ventilate at one and the same time. His latest stove combines many advantages and is adopted at Lincoln's Inn by Mr. Waterhouse. The incoming air is received into a sub-basement purifying chamber after it has been cleansed of all impurities by passing through a moistened filtering apparatus. The air so purified is conducted by flues to a chamber underneath the iron hearth of the new stove, which stands clear of the walls and allows the fresh air, after taking a

tortuous passage through the warm-air chambers of the stove to rise out of and over the centre of the stove into the room, on the same principle as that of Mr. Whitehurst, but pure, sweet and warm, and in large quantities. The air flue ceases at the stove hearth, but is continued again above the same in the form of a smoke flue from the upper part of the stove. No other ventilation than this incoming air withdrawn, after its revolution through the room, by the open fire-grate, is necessary, when there are not more than four or five persons, but in class-rooms and where numbers congregate supplementary inlets and extract shafts would be required if the exchange of from 750 to 3000 feet per head per hour is to be maintained. It is more than twenty years since I used Mr. Boyd's cast-iron flue plates to divide smoke flues, the merit of which was that the 4½ withe was left hollow between the smoke flues, and provided at a minimum of cost and space, a warmed air extract shaft for ventilating the apartment without entering the smoke flue. I used them with success in 1861, when I erected Mr. Horniman's house on the Warren Hill at Croydon. Then there is Mr. Henry Saxon Snell's "Therm-hydric Ventilating Hot Water Open Fire Grate." This invention consists of an open fire-grate surrounded on three sides and on the top by a wrought-iron chamber containing water, which when warmed by the fire circulates through upright coils of pipes placed on either side. The hearth is made of iron, and the whole space below the grate and pipes is formed into a chamber for the admission, collection, and warming of air from the out-side. The air cannot be burnt or be heated above the temperature of boiling water, and the water contained in the vase, being slightly warmed, evaporates and thus keeps the air of the room moist. I have drawn attention to this stove because it was approved and used at the Norfolk and Norwich Infirmary and elsewhere by the late Mr. Thomas Henry Wyatt, whose practice in hospital building was extensive and carefully studied from a sanitary point of view. This leads me to refer to his latest work carried out in association with his son, who now acts as architect to the New Hospital for Consumption at Brompton; my attention to which hospital was called by my friend Dr. R. E. Thompson in a letter describing the heating and ventilating processes, in which he has greatly interested himself.

Dr. Thompson thus summarises his own views:—"I think that air should be admitted at the level of the various floors, and not from an underground chamber; also that the air so admitted should come from the east and west sides if practicable, and should in any case be passed over tubes of hot water. Air of uniform temperature is disagreeable and oppressive, it is better that the upper air should be colder than that of the floor, and that the warm air as it rises from the floor level should be cooled and agitated as it mixes with the upper air by the incoming cooler air. The foul air should be extracted by the open fire and by the extracting flues at the top of the room, which should be heated by gas jets below, or made to communicate with a hot-air chamber above and in connection with turrets forming ventilating towers." With regard to water-closets he considers that the rooms they occupy should be heated to a higher temperature than the passages leading to them, and a separate means of extraction should be adopted—and he is right. These principles have been attempted to be carried out at the New Hospital. Mr. Haden has been entrusted with the heating and ventilating arrangements under contract to change the

air some 4000 feet per head per hour. He has provided low-pressure coils to stand in the recess formed by the back of nearly every window in the building, through which the external air is to come by the gratings provided under every window. The rooms will be rather over than under ventilated. Open fires are in every ward, and extract shafts as required, communicating with the hot-air chamber which surrounds the attic at the base of the mansard roof, and is connected with the four ventilating towers. The hot-air chamber is heated by the steam pipes from the engine boilers in the basement. The boilers for heating the hot-water piping are very large, but when cost and space is not a difficulty, the low-pressure system is most manageable and least deleterious in its action upon the air which is warmed by contact with its surface.

I agree with Dr. Thompson that there are some disadvantages in the system which has been adopted in many important buildings with varying success, namely, that of underground reservoirs for the accumulation of heated air to be transmitted through shafts to the different rooms in a building, the fresh air being admitted to this heated chamber through the floor of it. I have adopted it myself at the Choir Schools attached to St. Andrew's Church, Wells Street, using low-pressure piping—with the effect on the walls noticed at Magdeburg. It has been employed at the Johnson Street Board Schools at Stepney, and many other buildings, but notably that of Sir Josiah Mason's Science College at Birmingham. A chamber about 7 feet high and 9 feet wide and above 100 feet long is filled from end to end with low-pressure hot-water pipes, and the brick arch forming the floor is also the roof of another chamber for the reception of the fresh air from without, which is admitted through the same by the openings left for that purpose. The flues conducting the air to the several rooms lead from this chamber, and the current of air is very strong, carrying the warmed fresh air which is admitted at pleasure by gratings provided with a means of limiting the supply to suit the needs of the moment. Everything depends on the cleanliness of these vast chambers, and there have been cases in which, from the carelessness of the attendants, decayed organic and vegetable matter has been allowed to accumulate in or near the chambers, and in one case within my knowledge, a defective soil drain delivered its contents therein. It is obvious that the whole institution is rendered unwholesome if anything go wrong with this great lung of the building, whereas by separately heating each apartment, any defects are confined to the space where the damage may have occurred. It has been found in practice that cumbersome systems of ventilation are less manageable and more costly than simpler means, and in not a few cases, both here and in Paris, the original comprehensive plan of artificial ventilation has been superseded by less ambitious but more effective means. There are circumstances wherein a system of heating and ventilating by propulsion is alone applicable, and wherever a strong draught is required to draw off the vitiated air of any building, or where great distances have to be traversed, no more effective means can be resorted to, especially where a steam or gas engine is available for the motive power required to turn the fans.

In the new Technical Schools at Finsbury is an example of heating and ventilating by propulsion. The heating surfaces are placed in a common central chamber, with fresh air driven over them by two powerful fans and distributed by means of horizontal channels through the whole building, connected by means of rising shafts to each floor and room,

and delivering into the upper part of the same. High-pressure wrought-iron small-bore piping is to be used, of which the heating chamber contains some 3500 superficial feet. The boilers are adjacent—and so is the three-horse power engine required for driving the fans, which are 7 feet in diameter with blades 3 feet 6 inches across; 100 revolutions a minute are made, delivering the air at the rate of 15 feet per second, but it is made to enter the rooms at the rate of 3 or 4 feet and not exceeding 6 or 8 feet per second. Taking the air from the outside at a mean winter temperature of 39°, 1,640,000 cubic feet of air can be driven through the building per hour—each fan blowing one-half of the above quantity. The air is driven into the hot chamber, entering at the bottom, and is compelled by a plate-iron division to pass up and down through the heating surface before reaching the main distributing channel, which passes under the flooring right and left, graduated in area according to the number and size of the upcast shafts it has to serve. The iron gratings through which the warm air is forced into the rooms are sufficiently large to permit of a current of 3 or 4 feet per second, and are fitted with valves to regulate the supply. The fresh warmed air is admitted, either above or below the ordinary level of the pupils' heads, by a double set of ventilators. For the exit of the foul air, shafts are left in the walls running through to the roof, having extract openings into them near the floor or ceiling and as far as possible from the fresh air inlets, and thus provision is made for both summer and winter ventilation. The central chimney shaft from the furnace in basement rises to the height of 120 feet, and is not now used for drawing off the foul gases and vapours from the great laboratory and experimental closets in the various chemical departments, these being withdrawn by a special fan and shaft. There are above a dozen large stink-closets to be evacuated once every minute, from which collectively 52,320 cubic feet of air are drawn off per hour; and there are forty-seven draught-tubes from the various operation-benches, which withdraw 141,000 cubic feet per hour. In summer the fans drive in cold fresh air by the shafts, the pipes of the heating chamber not being at work as in the winter; and it can be admitted at the top or the bottom of the rooms at pleasure. The extract shafts which in winter are at the bottom, in summer are at the top or near the ceiling.

In concluding this very general statement of the necessary alliance between Sanitary Science and the practice of Civil Architecture, I have said enough to indicate its great importance and to ensure the incorporation of hygienic principles with the construction of Technical Schools and College Buildings, to the development of which branch of professional work this volume is specially devoted.

THE END.

SANITARY SCIENCE IN ITS RELATION TO CIVIL ARCHITECTURE.

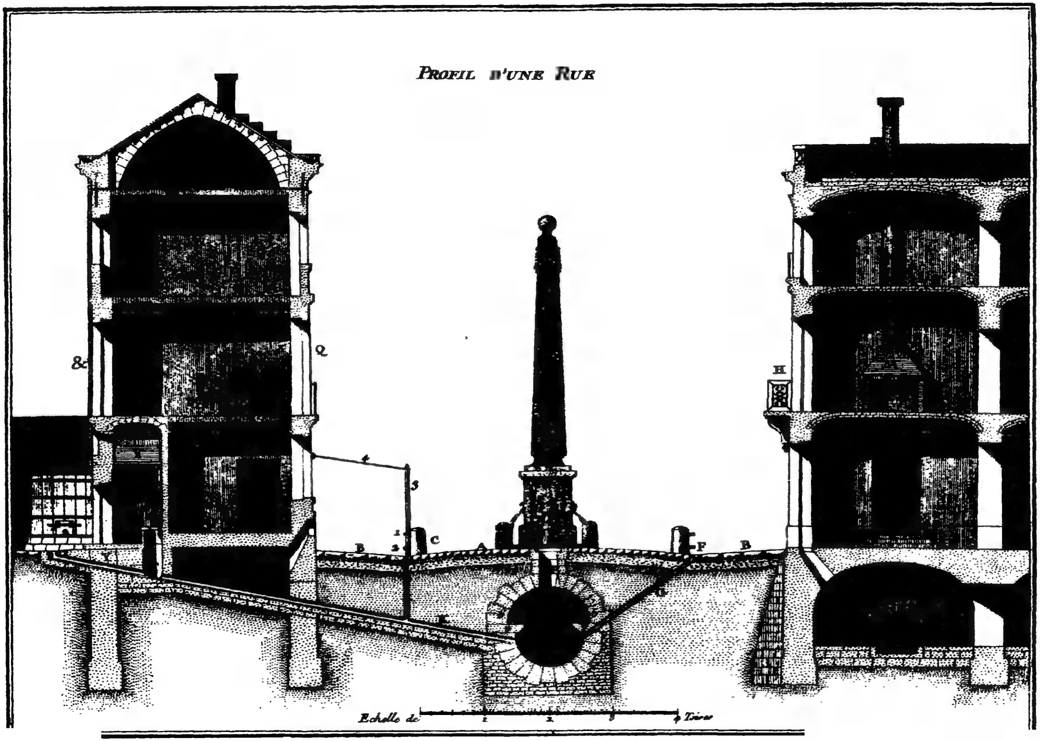
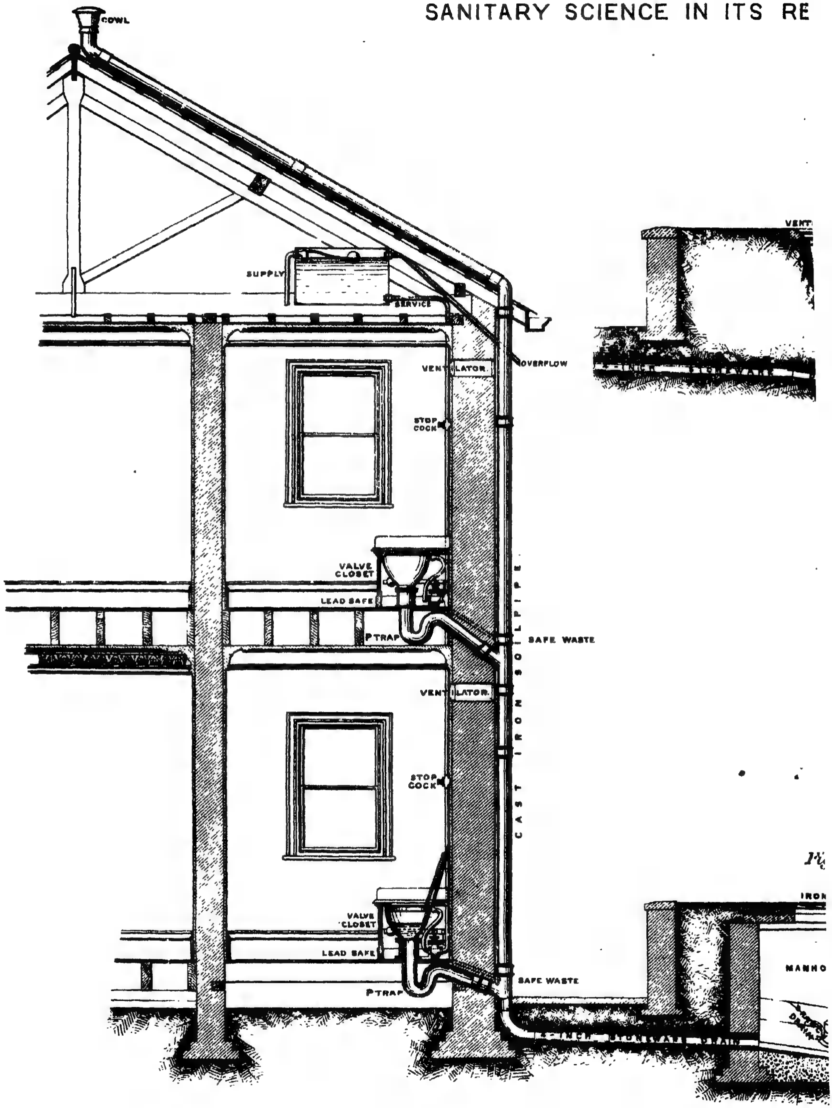


PHOTO-LITHO. OF PATTE'S DESIGN FOR DRAINING PARIS, A.D. 1769.

SANITARY SCIENCE IN ITS RE



SYSTEM OF HOUSE DRAINAGE B

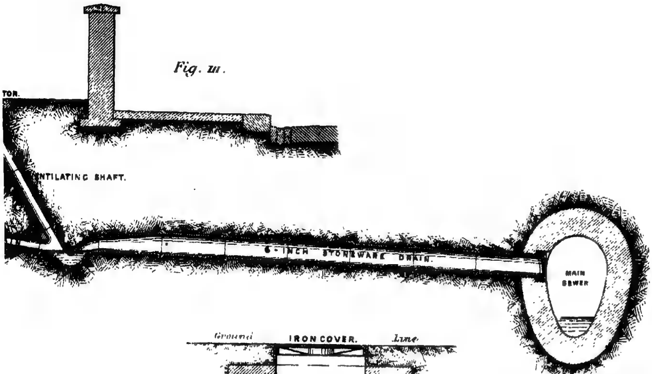


Fig. III.

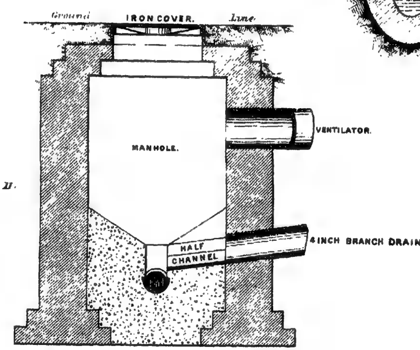
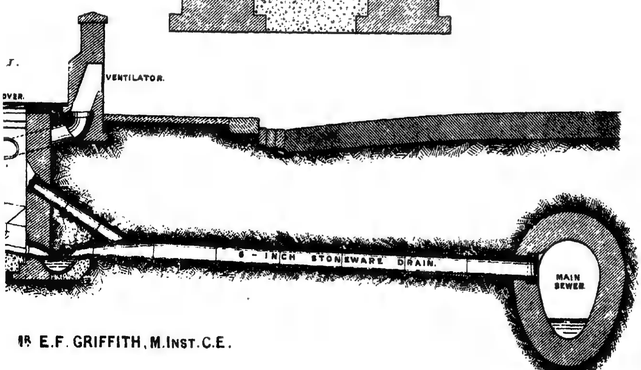


Fig. II.



ᴵᴮ E.F. GRIFFITH, M.Inst.C.E.

SANITARY SCIENCE IN ITS RELATION TO CIVIL ARCHITECTURE.

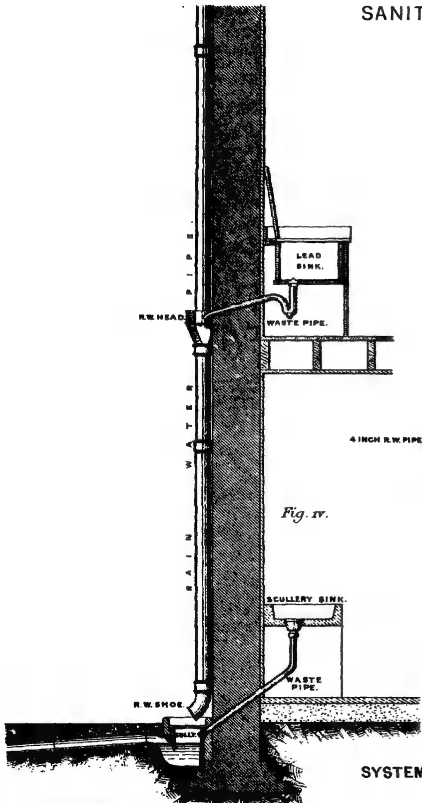


Fig. IV.

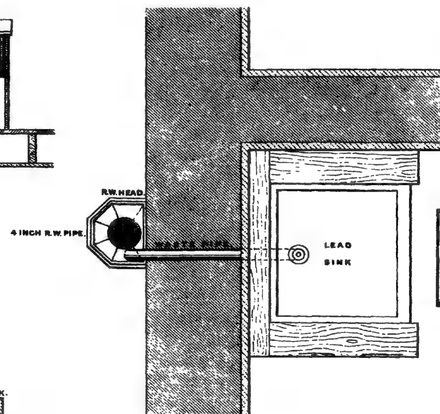


Fig. V.

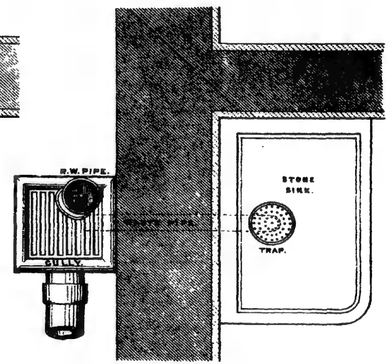


Fig. VI.

SYSTEM OF HOUSE DRAINAGE BY MR E.F GRIFFITH, M.INST. C.E.

E F. Griffith. Delt

APPENDIX.

APPENDIX.

Particulars as to several Technical Schools in the United Kingdom, and as to some on the Continent and in America, &c., prepared for the Borough of Blackburn by J. B. McCallum, January, 1887.

A.—TECHNICAL SCHOOLS IN THE UNITED KINGDOM.

Present Population of Town.	Name of Technical School.	Area occupied by Buildings.	Cubical contents of Buildings.	Total area of Site.	Cost of Land.	Cost of Fabric.	Cost of Furnishing, Appliances, Machinery, and Fittings.	No. of Students.	Yearly cost of Maintenance.	REMARKS.
	The Central Technical Institute, South Kensington.	2760 square yards	1,617,512 cubic feet.	5040 sq. yds.	......	80,000*l.*	25,000*l.*	About 300	......	This is intended for a Technical University, or College for the Kingdom.
	The Finsbury Technical School.	800 square yards, 120 feet × 60 feet.	Basement and three storeys above.	...	Ground Rent of 200*l.* a year.	21,000*l.*	15,000*l.*	150 Day 750 Evening	Fees ... ... £1750 City and Guilds ... 6000 £7750	Sir P. Magnus considers this a typical Technical School. Annual grant from City and Guilds' Institute of 6000*l.*
339,000	The Yorkshire College, Leeds.	About two acres	......	3½ acres	13,000*l.*	60,000*l.*	20,000*l.*	506 Day 300 Evening	Fees ... ... £4200 Grants ... ... 700 Endowments ... 1700 Voluntary assistance 2800 £9400	These figures are exclusive of the Medical Department of the Yorkshire College, but they include the departments of Science and Arts, as well as that of Technology. The last department includes Civil, Mechanical, Mining, and Electrical Engineering; Coal Mining, Chemical Technology Cloth Manufacture, Dyeing and Printing Textile Fabrics, &c. The buildings for Cloth Manufacture and Dyeing were erected by the Clothworkers' Company at a cost of 30,000*l.*, and the work therein is maintained by them by an annual grant of 1500*l.* These sums are included in the amounts tabulated.
219,000	The Bradford Technical School.	2900 square yards	......	4000 sq. yds.	3500*l.*	26,000*l.*	9000*l.*	1200, mostly Evening Students.	Fees ... ... £2043 Grants ... ... 1595 Other sources ... 1180 Voluntary assistance 2235 £7053	At a Public Meeting called by the Mayor in 1878, 11,000*l.* was promised. Clothworkers' Company gave 3500*l.* and an annual subscription of 500*l.* Many manufacturers give free Scholarships for two years' instruction.
376,000	The Manchester Technical School.	900 square yards	500,000 cubic feet. Basement and four storeys.	900 sq. yds.	Originally 4*l.* 10*s.* per yard, with chief of 6*d.*	In 1858, 12,500*l.*, including old Fittings, now further adapted.	2000*l.*, in addition to original cost.	2200	Fees, Grants, &c. £2900 Voluntary assistance 800 £3700	Building erected 29 years ago as a Mechanics' Institution. Subsequently altered for Technical School. 200*l.* per annum grant for six years, from 1883, from City and Guilds' Institute, and 100*l.* donation. Equipped with Engineering Appliances, Spinning and Weaving Machinery, and four Laboratories.
434,000	The Mason Science College, Birmingham.	1745 square yards	Basement and three storeys.	...	20,000*l.*	60,000*l.*	7000*l.*	360 Day 200 Evening	8000*l.* Endowment and Students' Fees amount to 7000*l.*	Built and endowed by Sir J. Mason. Additional subscribed endowment fund of 5391*l.* Chiefly University teaching. Special teaching in Engineering and Mining.
101,000	The Harris Institute, Preston.	867 square yards, including new addition and Chemical Laboratory.	334,800 cubic feet. Basement and two storeys.	867	Site given in 1846	10,000*l.* New addition and Laboratory added 1885—2000*l.*	2500*l.* Laboratory Fittings cost 500*l.*	1384	Fees ... ... £359 Grants ... ... 551 Endowments, &c.... 1135 £2045	Students on Register, 2096. Building, three storeys high. No. of Class-rooms, 17. Endowed by Harris' Trustees in 1882—40,000*l.*
95,000	The Huddersfield Technical School.	1933 square yards	926,000 cubic feet	3833	Leased for 999 years, at 121*l.* 4*s.* 10*d.* yearly.	21,000*l.* (Fabric and Furnishing).	Included in cost of Fabrics.	2080	Fees ... ... £1500 Grants ... ... 600 Voluntary assistance given and required, 1886: Endowments ... 450; Clothworkers' Company ... 200; Annual Subscriptions 400; Deficiency ... 350 £3500	Contains a Weaving Shed, 93½ × 41½ feet. Dye-house, Chemical Laboratories, School of Art, Mechanical Drawing Rooms, &c. Clothworkers's Company gave 2000*l.*
250,000	The Belfast Technical School.	Buildings, temporary.	132,000 cubic feet	...	......	1445*l.*	Included in cost of Fabrics.	65	Fees, &c. ... ... £89 Voluntary assistance 571 £660	The Drapers' Company, 250*l.* a year, and 50*l.* extra for Chemistry. Eleven Power-looms driven by 8 h.-p. Gas Engine. Instruction given in Flax Spinning and Flax Cultivation; in Weaving and Pattern Designing.
25,000	The Nottingham Technical School.	Buildings, temporary.	Six Workshops averaging 30 × 25 feet.	...	Rent of 150*l.* per annum.	......	1500*l.*	20 Day 110 Evening	950*l.*, including 150*l.* rent. Voluntary assistance, 570*l.*	There are 110 boys attend in day-time, for two hours a week, from the Elementary Schools for Instruction in use of Tools; 50 more next term. Grant of 300*l.* a year from City and Guilds' Institute for five years, and 200*l.* donation.

Institute.

[illegible]	The Keighley Mechanics Institute and Technical College.	2364 square yards	1,104,200 cubic feet.	3735	Included in cost of Fabric.	30,000*l.* (Land, Fabric, and Furnishing).	Included in cost of Fabric.	150 Day 1067 Evening	Including Salaries, 3000*l.* Voluntary assistance, 360*l.*	Opened in 1870. North-wing now approaching completion; when opened, cost of maintenance will be increased. Clothworkers' grant, 100*l.* per annum.
521,000	The Glasgow Technical Schools.	......	......	...	......	......	......	...	......	There are several Institutions in Glasgow where Technical Instruction is given: Allen Glen's Institution, Glasgow College of Science (51*l.* per annum from City and Guilds' Institute), Anderson's College, Glasgow Weaving Schools, and others.
254,000	Heriot Watt College, Edinburgh (Technical Department).	1443 square yards	908,684 cubic feet	1547	Site and Building handed over by Watt Institution	19,000*l.* (Estimated cost of additions now in progress).	......	2100	Revenue from Endowment, 4500*l.*	New Building being erected. Cost to be defrayed by Sinking Fund from annual revenue.
220,000	The Merchant Venturers' School, Bristol.	......	......	...	5500*l.*	35,000*l.*	4000*l.*	400 Day 415 Evening	......	A Trade School refounded by the Society of Merchant Venturers of Bristol. A Mining and Technical department. Practical Chemistry and Assaying. Well-equipped Laboratory.
130,000	The Oldham School of Science and Art.	640 square yards	300,000 cubic feet	640	1100*l.*	10,000*l.*	Included in cost of Fabric.	625	Fees ... ... £302 Grants ... ... 497 Voluntary assistance 480 £1279	Annual subscriptions, 500*l.*
139,000	The Leicester Technical School.	......	......	...	......	5200*l.* (Fabric and Furnishing).	......	220	Fees ... ... £37 Grants ... ... 52 Voluntary assistance required 71 £160	700*l.* given by City and Guilds' Institute.
110,000	The Bolton Church Institute Science and Art School.	600 square yards	Two storeys	1 acre	Given by Lord Bradford, and Bishop of Chester.	[illegible]	Included in cost of Fabric.	150 Day 600 Evening	Fees ... ... £1615 Grants ... ... 828 Voluntary assistance 207 £2650	The Day Schools are Higher Middle Class, and the profits are available for the maintenance of the Science, Art, and Technological Classes. There are two large halls and nine smaller rooms.
115,000	Robert Gordon's College, Aberdeen.	......	......	...	Site given	Value, including Fittings, 17,500*l.*	......	900 Day 1300 Evening		

NOTE.—The Drapers' Company has recently endowed the People's Palace, London, with 20,000*l.* for the establishment of Technical Schools and Workshops. The City of Worcester has decided to spend 7000*l.* in assisting to build Schools to cost 18,000*l.*

B.—TECHNICAL SCHOOLS ON THE CONTINENT AND IN AMERICA, &c.

65,000	Weaving and Spinning School, Mulhouse	Cotton. Supported by the Manufacturers. English and Alsatian Spinning Machinery. Buildings, substantial and two storeys high.
107,000	Hanover Technical High School	Area occupied by Buildings, 300 feet × 250 feet. Chemistry, Geology, and Engineering.
1,315,000	Berlin Artisans' Society	Founded in 1859. Classes for Technical Education. No. of members, 2246. Public Lectures by eminent men. Building Trade School in connection.
75,000	Weaving School, Crefeld	Cost, including Land, 47,500*l.* Very complete School. Opened 1883. Weaving Shed, 940 square yards. Electric Light. Library of 1200 Textile and Art Books.
111,000	Higher Trade Institute of Chemnitz, Saxony.	Completed in 1877. Cost 52,000*l.* Special Cotton Spinning and Weaving Machinery. 531 Students. State subsidy, 7700*l.* Town, 240*l.* Fees, 1234*l.*
2,500,000	The Conservatoire National des Arts et Métiers, Paris.	Drawings of latest English Machinery—especially Textile—on view. Free popular Lectures. General Chemistry, with its application to Industry. Spinning and Weaving.
75,000	Industrial Society of Amiens	Chemistry, applied to Dyeing, Weaving, &c. Day and Evening Classes.
65,000	Industrial Society of Rheims	Good Building, with Class-rooms and Lecture-theatre. Lectures on Weaving, Chemistry, &c. Evening Classes.
376,000	École des Beaux Arts, Lyons	Great attention paid to Designing and Drawing. Grant from City of Lyons, 222*l.* per annum.
376,000	Lyons: Société d'Enseignement Professionnel du Rhone	This Society, formed in 1864, is attended yearly by nearly 8000 Students. Some Classes held in Schools and some in Special Rooms. Taught, amongst other things, Mathematics, Drawing, Weaving, Stone Cutting, and Hygiene. Fuel, and the Steam Engine, a special study.
120,000	École Industrielle at Liege	Recently erected. Cost [illegible]*l.* Model Building.
376,000	The École Commerciale, Lyons	Silk Weaving School—14 Looms. Courses of Lectures given on Weaving and Designing to Artisans.
124,000	St. Etienne: Weaving School—(Silk) ...	Pattern Designing practically taught. [illegible] Pupils. Town Council give annually 1200*l.* to this School. Manufacturers give Prizes.
92,000	Roubaix: Weaving School—(Silk) ...	Weaving and Dyeing. New Building to cost [illegible]*l.*
45,000	Verviers: Manufacturing School	Cost 20,000*l.* Weaving and Dyeing. Maintained, one-third by Town and two-thirds by State. The annual grants being [illegible]. New Building to be erected, towards which the Manufacturers give [illegible]*l.*
130,200	The École Industrielle of Ghent	Fine Building, recently erected. Chemistry. Machine Drawing. Building Construction. Weaving School. Ghent being the centre of the two great Textile Industries—Cotton and Flax—is the reason of the existence of this special school at Ghent. Pupils attend Lectures on Weaving and work at Looms. Three afternoons per week devoted to Ornamental Designing and to putting the design on the loom. Industrial Art School in connection to train Designers for Textile Fabrics, &c. About 1000 Students. Expenses [illegible]*l.* a year. State and Municipal grants.
25,100	Zurich: Weaving School	Opened in 1882. Large house converted to present use. 45 Students.
194,000	Royal Technical High School, Stockholm	3500*l.* granted by the State. Library of 15,000 volumes, and [illegible] English Patent Office Specifications. Land and Fabric cost 31,000*l.* Number of Students, 300. Yearly cost of Maintenance, [illegible]*l.*
81,500	The Chalmers Industrial and Technological School, Gothenburg, Sweden.	Spinning, Weaving, Navigation, Hydraulics, Chemistry, and Mechanics. Founded in 1829 by a Merchant of English origin. [illegible] Students. Annual Income, 2000*l.*
1,104,000	Vienna Fach-Schule for Jewellery, &c. ...	Chemistry, in relation to Metal Working. Practical Metallurgy. 150 Students. Instruction gratuitous.
731,000	Imperial Technical School of Moscow ...	To train Mechanical Engineers and Chemists. Foundry. Spinning of Cotton Flax, and Wool Weaving. Bleaching and Pattern-making. 600 Students.
1,800,000	Columbia College, New York	Mining, Engineering, Geology, Metallurgy. No. of Students, [illegible], of whom [illegible] attend School of Mines.
[illegible]	Cooper Institute, New York	Technical Night-school, free to both sexes. No. of Pupils, [illegible]. Electrical Engineering.
847,000	Spring Garden Institute, Philadelphia ...	Mechanical Workshops. Yearly expenditure, [illegible]*l.* No. of Students, [illegible]. Library of 12,000 volumes.
1,315,000	Technical High School, Berlin	665 × 170, and [illegible] feet high. Cost about [illegible]. Accommodation for 2000 Students. Opened 1884.
[illegible]	Poonah College, Bombay	The Town Council have voted 5000 rupees to aid Artisans in Technical Works.
[illegible]	Miller Manual Labour School, Albemarle, Virginia.	Endowment, 1,275,458 dollars. Opened 1879. One of the largest Technical Schools in the United States.
1,315,000	Berlin Technological Engineering School, Charlottenberg.	Provision for 2000 Students. Cost 500,000*l.* *Built by the State.*
861,000	Imperial Technical School, St. Petersburg	The Buildings cover two acres, and are three storeys high. Total Expenditure, [illegible]*l.* 700 Students. Established 1828.
302,000	The Boston School of Technology, Massachusetts.	This is considered by Mr. Mather to be the best Technical School in the World. Civil, Mechanical, Electrical, and Mining Engineering. Architecture, Chemistry, and Geology. Buildings and Land cost 65,000*l.*

NOTE TO PAGE 184.

IN the Philosophical Transactions of the Royal Society of London, 1887, vol. 178, is a paper on "The Carbonic Acid, Organic Matter, and Micro-Organisms in the Air, more especially of Dwellings and Schools," by Professors Carnelly, Haldane, and Anderson, of Dundee. In the chapter on "The Air of Schools," the result is given of a comparative analysis of the impurities contained in the air of sixteen board schools, five secondary schools, and the lecture-rooms and chemical laboratory of the University College at Dundee. Some of the above buildings were naturally and others mechanically heated and ventilated. Those that were mechanically heated were provided with the system known as "Cunningham's," of which a description is given in pages 182, 183, and 184. Tables are given which show that with mechanical ventilation, the space per person being the same:—

(1) The carbonic acid was three-fifths, the organic matters one-seventh, and the micro-organisms less than one-ninth of what they were in schools ventilated by ordinary natural methods.

(2) That, notwithstanding this very great improvement in the purity of the air, the temperature is very considerably higher in the mechanically ventilated schools.

The results show that the cubic space per child would not require to be nearly so great, in order to maintain a given standard of purity, on the mechanical as on the natural system. Hence the cost of heating and of building would be reduced in proportion.

In comparing girls' schools with boys', it was found that the temperature of the former was always lower than the latter, and that there was an average of one-fifth less carbonic acid evolved, one-seventh less organic matter, and one-third less micro-organisms in the air of girls' schools than in boys' schools. The original research detailed in this paper is of the utmost value to school-builders, technical or otherwise.

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